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FEBRUARY, 1931

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UNITED STATES DEPARTMENT OF AGRICULTURE
WEATHER BUREAU
WASHINGTON, D. C.

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CORRECTIONS

Volume 57, December, 1929, page 529: In the first column, second paragraph from bottom, third line of the "NOTE," omit the minus sign before "58.7° C."

Monthly Weather Review Supplement No. 34 (The Daily, Monthly, and Annual Normals of Precipitation in the United States, page 30: The total annual precipitation (Erie, Pa.) should be "36.93" inches.

MONTHLY WEATHER REVIEW

Editor, ALFRED J. HENRY

VOL. 59, NO. 2
W. B. No. 1039

FEBRUARY, 1931

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A PRELIMINARY METEOROLOGICAL SURVEY FOR AIRSHIP BASES ON THE MIDDLE ATLANTIC SEABOARD

By WARD T. VAN ORMAN

[Goodyear-Zeppelin Corporation, Akron, Ohio]

Location of a base for an airship terminal is analogous to the selection of proper docking facilities for ocean-going vessels. In addition to the usual docks required at any location, a natural harbor is always selected. These harbors, provided by nature, are visible, tangible things whose suitability may be quickly judged. In the case of aircraft, we maintain that there exist similar natural air harbors, however invisible and intangible. By meteorological and climatological analyses the location of these natural air harbors may be ascertained.

For a preliminary and general survey of the Atlantic coastal plain, we were fortunate in having the cooperation of the United States Weather Bureau and the Meteorological Services of the Army and the Navy. It is the purpose of this preliminary study to coordinate the data furnished by the above mentioned services in such a form as to isolate in a general way the desirable area from the undesirable on the middle Atlantic seaboard. Further examination is being made of wind conditions on possible sites in the area found generally favorable.

In a letter of May 8, 1930, the United States Weather Bureau issued detailed instructions for the compilation of the fundamental records used in this study. With the exception of the precipitation, temperature, and thunderstorm data, taken from the Atlas of American Agriculture, all data used in the study originated from the instructions of this letter.

In the selection of an airship base it is obvious that certain weather characteristics must have an important bearing. In this study particular emphasis has been placed on the following characteristics: Fog, snow, rain, thunderstorms, temperature, and winds. These factors influence the buoyancy of the ship, the ease of operation in flight, and handling on the ground.

Data pertinent to our conclusions are presented in complete detail in Appendix A of this report, copies of which are on file at the offices of the International Zeppelin Transport Corporation; the Pacific Zeppelin Transport Co. (Ltd.), in New York City; the Goodyear Zeppelin Corporation at Akron, Ohio; the United States Weather Bureau; the Aerological Office; United States Naval Air Station, Lakehurst, N. J.; and the offices of the heads of the Army and Navy Meteorological Services at Washington, D. C.

The following charts are taken from the above-mentioned Appendix A and are indicative of conditions exhibited by other charts in the same study, and presented as representative charts applicable to this study.

The following paragraphs discuss briefly weather conditions affecting the desirability of areas under consideration for airship bases.

Temperatures.—The lifting characteristics of airships are dependent on temperature. With increased temperature in the summer time, the outside air density decreases and the ship loses in lift for a given volume. Low temperatures are to be avoided in the winter months even though they are productive of increased lifting power of the airship, for the reason that low temperatures are frequently accompanied by snow and glaze storms. In addition, labor necessary for the maintenance of airships becomes inefficient at low temperatures. The lines on Chart 6 show the average daily temperature in summer. It will be noted that an increase in temperature occurs to the south of Washington. Due to the resulting loss of buoyancy in the summer time, the area to the north of Washington or perhaps Richmond would be desirable. For winter operating conditions (charts for which closely parallel Chart 6, but with an approximate reduction of 40°) the desirable area would be south of the line between Trenton and Harrisburg.

Temperature range.—Fluctuations in temperature cause the lifting gas of an airship to expand and contract. The maximum volume of an airship, of course, is fixed, and the lifting power is, therefore, limited by the maximum temperature. Large fluctuations in temperatures exercise a harmful influence on buoyancy and economy of operation; therefore, small fluctuations of temperature are desirable at an airship terminal. Such fluctuations in temperature are shown on Chart 8 for the summer months, exhibiting a maximum fluctuation in southwestern Pennsylvania. From this chart the desirability of close proximity to the seacoast is apparent. However, it will be shown later that wind conditions do not permit such close proximity to the coast, and, therefore, the desirable area should probably include Philadelphia, Baltimore, and Richmond. For daily fluctuations of temperature in the winter, Chart 9 is presented. Here again the desirability of staying close to the Atlantic seaboard is apparent, and also it is possible to obtain a very small fluctuation of temperature in the vicinity of Philadelphia, Baltimore, and Richmond. The stabilizing influence of the Atlantic Ocean is apparent on both charts.

Thunderstorms.—It is popularly believed that the hazards to aircraft from thunderstorms are dependent entirely on lightning. Recently, studies and flight experience indicate that the real hazards of flying in the vicinity of thunderstorms are the tubulence or whirlpools in the air and the squalls which accompany such phenomena. The desirability of avoiding such storms is apparent. For the study of thunderstorms the number of days per year with such storms is presented on Chart 10. It will be noted that a fairly constant increase in the number of

thunderstorms per year occurs from Trenton southwest to the Gulf States, where a maximum occurs. A reasonable area from a thunderstorm viewpoint is the Trenton Richmond area, in which 32 to 40 thunderstorms occur per annum.

Snow.—Snow influences the operation of an aircraft in two respects. On an airship moored to a mast the snow has a tendency to accumulate on the upper surface and add appreciable weight to the ship. This can be avoided by the use of ballast which is an inconvenience. In flight, the snow is blown off of the surface of the ship, and the only detrimental effect encountered is impaired visibility. It is anticipated, with recent improvements in mechanical handling of airships on the ground, that the ill effects of snow on the ground will be largely eliminated. Chart 11 shows the distribution of days per year with snow cover on the ground. It will be noted a marked decrease in the number of days per year with snow occurs southward and southwesterly from Philadelphia. More desirable conditions are apparent at Richmond.

Rain.—Rain has somewhat the same influence on the operation of an airship as snow. Considerable weight may be added to the craft when moored to a mast, or weight may be added in flight by a heavy shower. Impaired visibility, of course, accompanies rainfall. Chart 14 shows the number of days per year with rainfall and on this chart the entire middle Atlantic seaboard may be considered satisfactory.

For maximum rainfall in any 24-hour period, Chart 16 has been constructed. Here it is obvious that the most desirable location should be an appreciable distance from the seaboard, preferably 50 to 100 miles.

Fog.—In the study of fog, Chart 13 represents the average number of days per year with dense fog. On the chart, the optimum area is inclosed, showing Richmond, Washington, and Philadelphia to be satisfactory. Baltimore is a trifle high, but not seriously so. As is to be expected, the coastal stations of New York, Atlantic City, and Cape Henry are poor.

Docking.—The docking of an airship consists of transferring the ship from its location on the field into the hangar or dock. This operation is usually carried out in favorable wind conditions. It is apparent that a strong cross-hangar wind is productive of severe strains on the airship and some hazard of damage is present. Therefore, favorable wind conditions for docking can be judged by the occurrence of the lower wind speeds.

When the wind velocities are 5 miles per hour or under for one hour or more in 24, this condition is tabulated as a docking day. The average docking days per year are plotted on Chart 18 and the desirable area is inclosed. In the chart some consideration should be given to interpreting the values for Philadelphia and Trenton which were derived from the anemometer exposures of 190 and 180 feet, respectively. These high exposures are productive of higher wind velocity records than are representative for these locations. The optimum area includes Baltimore and Washington, and is very close to Richmond.

"No ground handling."—At higher wind velocities the handling of an airship in close proximity to the ground is somewhat difficult. This may be due to fluctuations in wind speed or turbulence produced by the air flow. The combination of wind fluctuations and the higher force of the strong wind itself can make the handling of an airship on the ground impractical. Such conditions are here described as "No ground handling" conditions. Chart 28 shows as "no ground handling" days, the times per year when winds of 13 miles per hour or over are encountered for the entire 24 hours. The optimum area in this case includes the Baltimore and Washington section.

Mooring delays.—Mooring of an airship consists of anchoring the ship to a high or stub mast by means of cables. This operation is possible in winds of higher velocities, but delay may be encountered when wind velocities of 30 miles or more are encountered.

Mooring delays per year are shown on Chart 34. When winds of 30 miles per hour or more are encountered for a period of 6 to 11 hours, that period is tabulated as a mooring delay. Attention is invited to the shape of the inclosed desirable area which closely approximates the shape of the inclosures of many of the wind charts exhibited in Appendix A. The desirable area includes Philadelphia, Baltimore, Washington, Richmond, and extends on southwesterly. Poor conditions are exhibited at coastal locations.

Distribution of wind velocities.—For another method of studying wind velocities, we have divided the velocities into the following limits: 0 to 5, 6 to 12, 13 to 20, and 21 or more miles per hour. The total number of hours which the wind blew within these velocity limits was used as a basis of this study. For the most desirable conditions we should look for a maximum number of hours for which the wind blew within velocity limits of 0 to 5 miles per hour, and conversely, a minimum number of hours for velocities of 6 or more miles per hour.

Chart 43 shows the total number of hours per year, averaged from 5-year data, that the wind blew within velocity limits of 0 to 5 miles per hour. The inclosed optimum area extends northward nearly to Philadelphia. There may be some question as to Hadley Field being included in the desirable area due to the break in conditions exhibited in the vicinity of Philadelphia. No accurate method was available to justify the exclusion of this station, and it was therefore included.

For velocity limits of 6 to 12 miles per hour, wind conditions are shown on Chart 44 giving total hours per year for this velocity limit. The inclosed optimum area has the usual characteristic shape with the exception that it includes Mitchell and Hadley Fields usually excluded on other charts.

Velocity limits of 13 to 20 miles per hour are shown on Chart 45. The shape of the optimum area is of the usual type with the exception that it includes Hadley Field in the area.

For velocity limits of 21 or more miles per hour, the hours per year are shown on Chart 46, showing the characteristic shape of the desirable area which includes Philadelphia, Baltimore, Washington, and Richmond.

Hangar orientation.—For study of wind direction applicable to hangar orientation the polar coordinate charts, Nos. 64 and 65, are incorporated as representing typical direction studies. It will be noticed on Chart 64, the days and nights with low winds of 0 to 5 miles per hour were excluded and the chart covered only those periods in which winds of 6 to 12 miles per hour were encountered for one or more hours. Some question may be raised as to the desirability of excluding those periods in which docking conditions of 0 to 5 miles per hour exist, but it was felt that the inclusion of those periods would merely mean the addition of a constant value to the radii of Chart 64. The prevailing wind direction is shown as a maximum westerly direction on this chart.

On Chart 65 the distribution of wind directions and velocities is shown by various limits of 6 to 12, 13 to 20, and 21 or more miles per hour. The wind direction on the chart is somewhat variable, but quite desirable from

a velocity viewpoint, showing predominance of winds of low velocities and low frequency of winds of a higher velocity.

SUMMARY

For a summation of the precipitation, fog, thunderstorm, and temperature conditions Chart 1 was devised. This chart represents a composite of *all* conditions other than wind, taken from Appendix A and superimposed upon each other to obtain the most desirable or optimum area. The shaded area in the chart represents the optimum area and includes Philadelphia and Washington. The isogram to the west of Washington is a temperature line, and therefore may be considered somewhat flexible, sufficiently so to justify the inclusion of Washington and perhaps Richmond in this area. Baltimore is slightly below normal on fog conditions. Richmond has slightly more thunderstorms and slightly higher summer temperatures but should be included in the desirable area.

Chart 2 represents a composite summary of all wind conditions described in Appendix A. The optimum area is shaded in this chart and lies slightly to the westward of Philadelphia and to the north of Richmond. Only one or two lines exclude Richmond and Washington from the optimum area, and therefore they should be included in that area. There is an apparent transition in the weather conditions in the vicinity of Philadelphia, becoming increasingly poor to the northeast. Therefore, as a northern limit to the desirable area, Philadelphia is included. Comparatively few lines exclude Richmond, which is likewise recommended for the desirable area.

Anticipating the development of mechanical handling of airships in higher wind velocities than has been common in the past, we have provided in Chart 3 a summary of all wind conditions and velocities of 21 miles per hour or more. This composite chart was likewise obtained from superimposing all wind charts above 21 miles per hour shown in Appendix A of this study and the optimum area is shown in the shaded portions. Philadelphia represents the northeastern limit of this area which also includes Baltimore. Richmond is excluded by a single line and Washington is in close proximity to the desirable area and these cities are, therefore, recommended to be included in the optimum area.

COMPARISON OF STUDY AND INDEPENDENT STUDIES

In order to align this study with similar efforts we have provided Chart 4, comparing the centers of the desirable areas with the average wind velocities. The lines for average wind velocities are taken directly from the Atlas of American Agriculture, Part 2, Section B, by J. B. Kincer. This phase of the chart was based on anemometer records of the 20-year period from 1891 to 1910, inclusive, taken at 175 Weather Bureau stations scattered throughout the United States. Corrections were applied for the heights of the anemometers to estimate the wind that would have occurred at the uniform elevation of 100 feet above the ground. It will be noted that a marked increase in velocity occurs from the Atlantic seaboard to the west and that the desirable area based on average wind velocity conditions alone would include Washington, Philadelphia, Baltimore, and Richmond. Low temperatures and snow would limit the northern extent of the area to Philadelphia, while the southern cut-off would occur south of Richmond due to high temperatures and thunderstorms.

To compare the average velocity features of Chart 4 with our study, a line in the center of the optimum area of each chart was drawn to represent the locus of maximum desirability. All charts in Appendix A, including the climatological and wind charts, were thus treated and superimposed on the average wind velocities of Chart 4. Obviously the location where the lines are the densest may be considered the optimum area. It is a striking feature of this comparison that the loci of the optimum points coincide with the desirable area as indicated by the average wind velocities. It is certainly to be expected that the various methods should be in reasonable agreement but in this case the conclusions are identical.

CONCLUSIONS

In Appendix A the statement is made that an examination of the study will show the desirability of keeping at least 30 miles back from the shore line of the Atlantic seaboard. This statement was based largely on summaries shown on Charts 2 and 3 showing the eastern edge of the optimum area to have a very definite relation to the Atlantic coast. However, if we wish to secure the most perfect conditions possible near the eastern seaboard, it would appear that, based on the evidence on Chart 4, the airship base should be about 100 miles from the Atlantic coast. This statement is in agreement with our present conception of the influence of large bodies of water. We know definitely from temperature studies, free balloon flights, and similar phenomena that the direct influence of the sea breezes extends at least 30 miles inland. Further, it is also reasonable, as indicated by this study, that the complete dampening influence of the surface friction of the land area is not fully effective until a distance of about 100 miles from the Atlantic seaboard has been reached.

It should not be inferred that ideal conditions will be encountered 100 per cent of the time in any section of the middle Atlantic seaboard. However, from the data herein presented, it will be seen that in the desirable areas outlined in this study, the best attainable conditions will be encountered. By using the weather conditions encountered at the Naval Air Station at Lakehurst, N. J., as a standard of comparison, it is apparent that the operating conditions to be encountered at the proposed locations of Richmond, Washington, Baltimore, and Philadelphia will be very much better than those of Lakehurst.

In conformity with the conclusions of this study and Appendix A, we recommend that the locations of Richmond, Washington, and Baltimore be considered for a trans-Atlantic airship base, and also that Philadelphia be included as representing the most northerly point that we can conscientiously recommend for consideration. On these four locations anemometers have been erected and continuous records are being taken of wind velocity and direction characteristics, and the final selection of an airship base will be made largely from records thus obtained. Such records are necessarily affected largely by local topography which influence may modify the general views developed from the preliminary and general survey made in this report. It is only to be expected that in the large area here found to be generally favorable there may be locations that are more favored by nature than others.

FIGURE 1 (CHART 1).—Summary of precipitation, fog, clouds, thunderstorms, and temperatures

FIGURE 2 (CHART 2).—Summary of all wind conditions, shaded area most desirable

FIGURE 3 (CHART 3).—Summary of winds of 21 or more miles per hour

FIGURE 4 (CHART 4).—Centers of optimum areas compared to average wind velocities in miles per hour

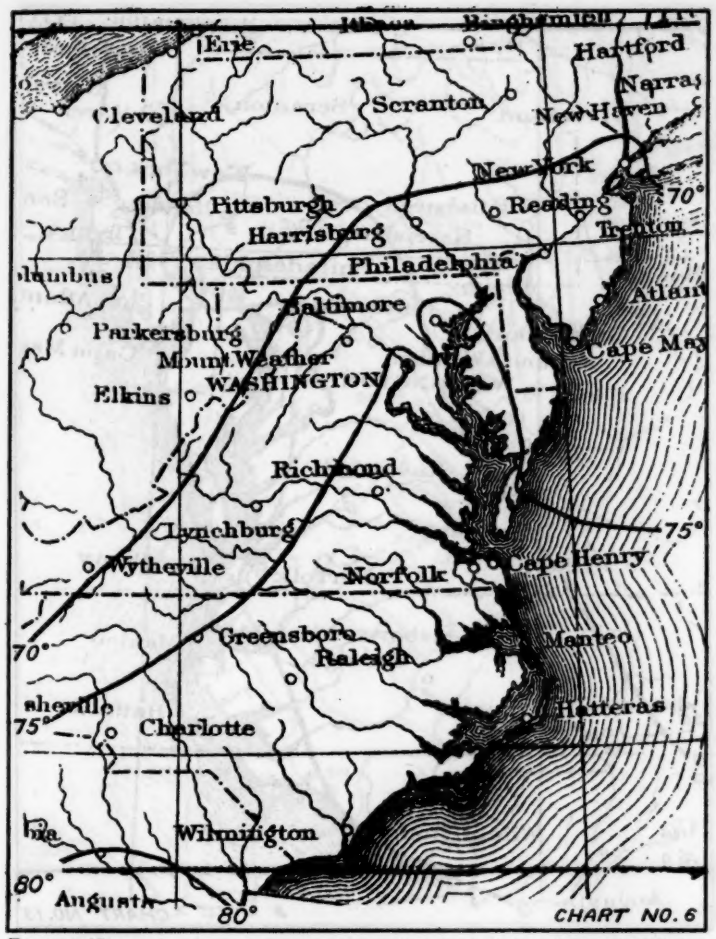

FIGURE 5 (CHART 6).—Average summer temperature, June, July, and August, 1895–1914

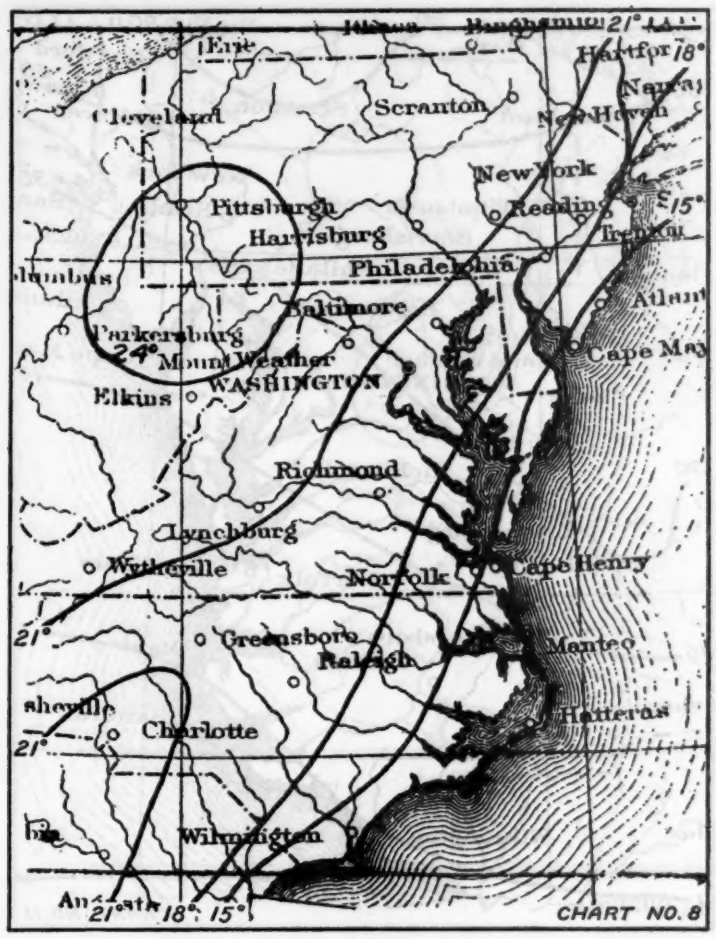

FIGURE 6 (CHART 8).—Average daily temperature range, July, 1895–1914

FIGURE 7 (CHART 9).—Average daily temperature range, January, 1895–1914

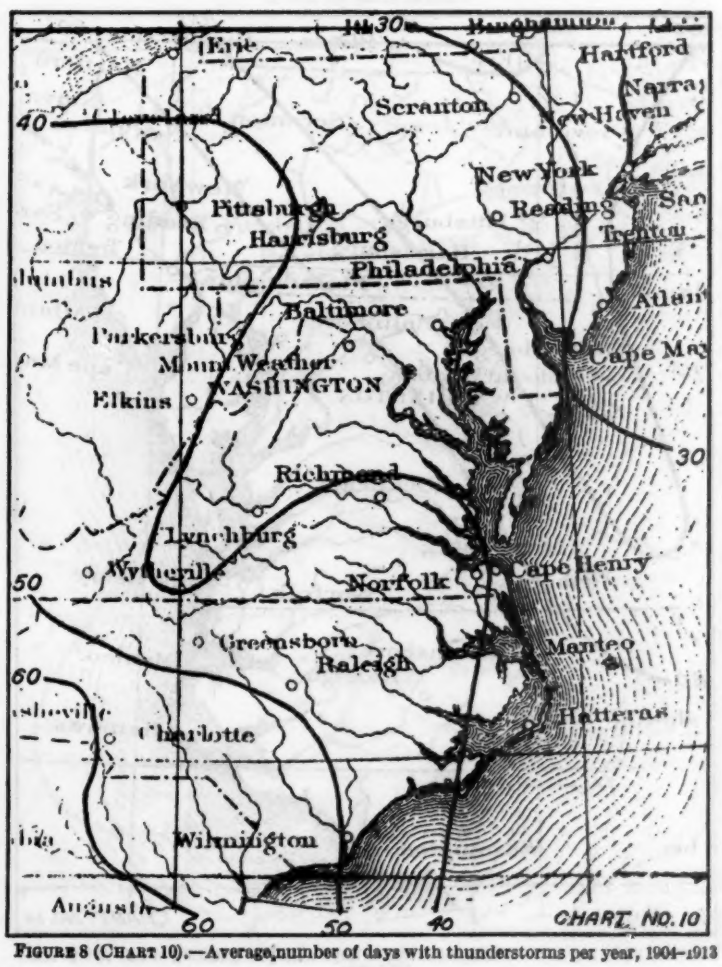

FIGURE 8 (CHART 10).—Average number of days with thunderstorms per year, 1904–1913

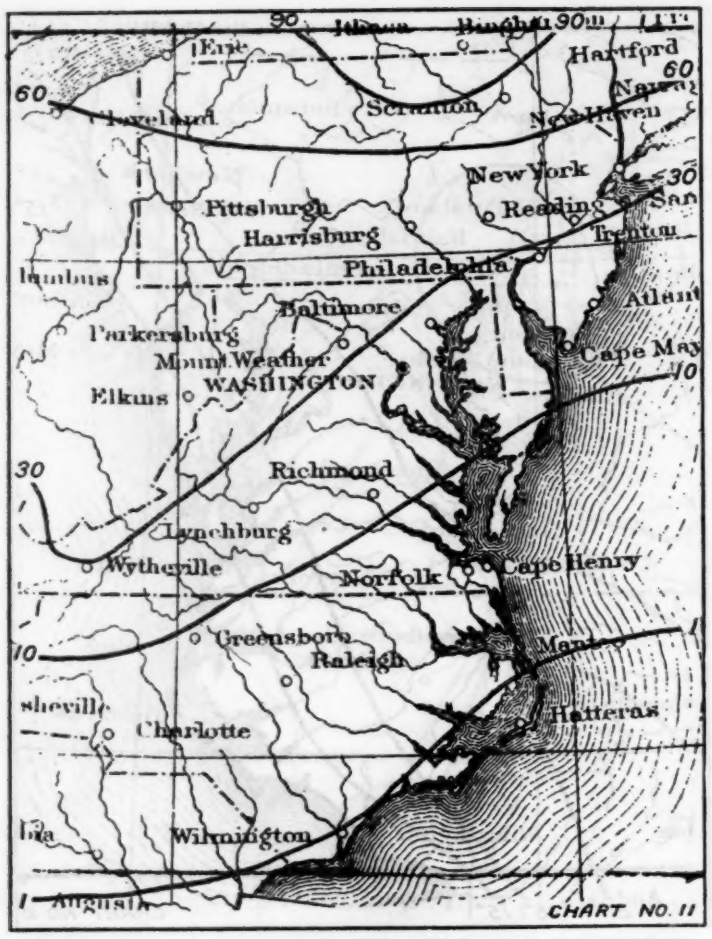

FIGURE 9 (CHART 11).—Average number of days with snow cover per year, 1895–1914

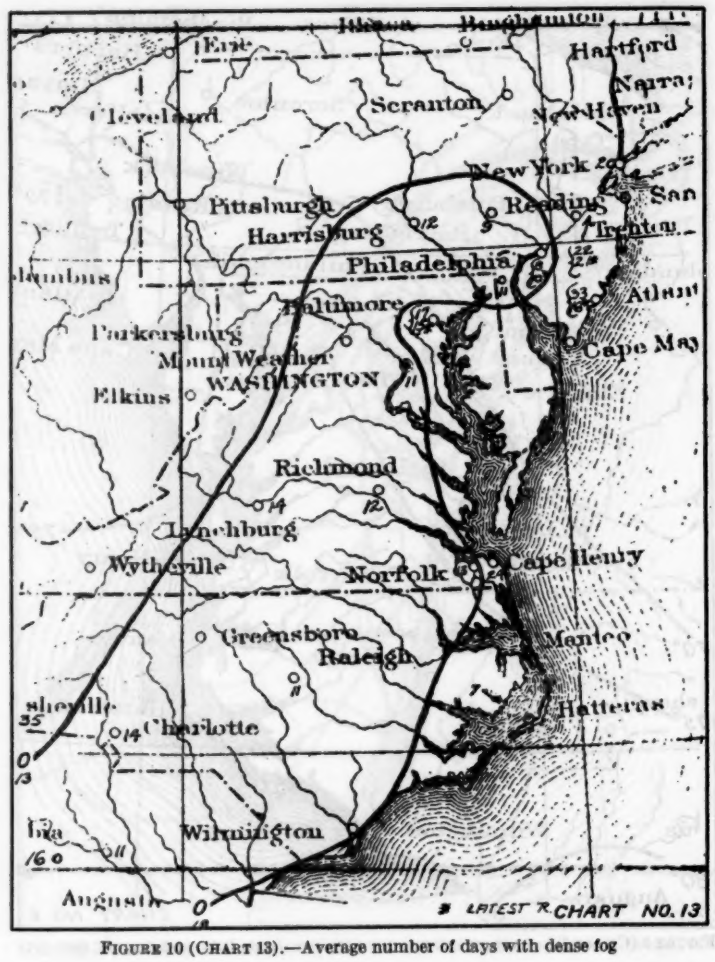

FIGURE 10 (CHART 13).—Average number of days with dense fog

FIGURE 11 (CHART 14).—Average number of days with precipitation of 0.01 to 0.25 inch, 1895–1914

FIGURE 12 (CHART 16).—Maximum precipitation in 24 hours, 1895–1914

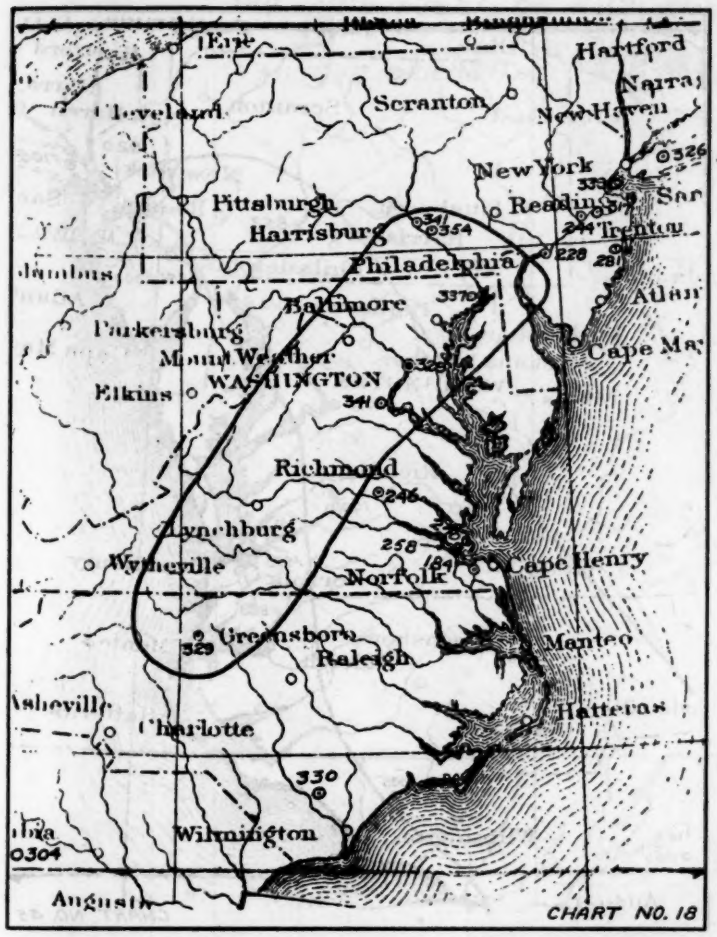

FIGURE 13 (CHART 18).—Docking days, 24 hours, winds of 5 miles per hour or under, for 1 hour or more

FIGURE 14 (CHART 28).—"No ground handling" days, winds of 13 miles per hour or over for entire 24 hours

FIGURE 15 (CHART 34).—Mooring delays, winds of 30 miles per hour or more, periods of 6–11 hours

FIGURE 16 (CHART 43).—Hours per year, winds of 0–5 miles per hour

FIGURE 17 (CHART 44).—Hours per year, winds of 6–12 miles per hour

FIGURE 18 (CHART 45).—Hours per year, winds of 13–20 miles per hour

FIGURE 19 (CHART 46).—Hours per year, with winds of 21 miles per hour or more

(To face p. 64)

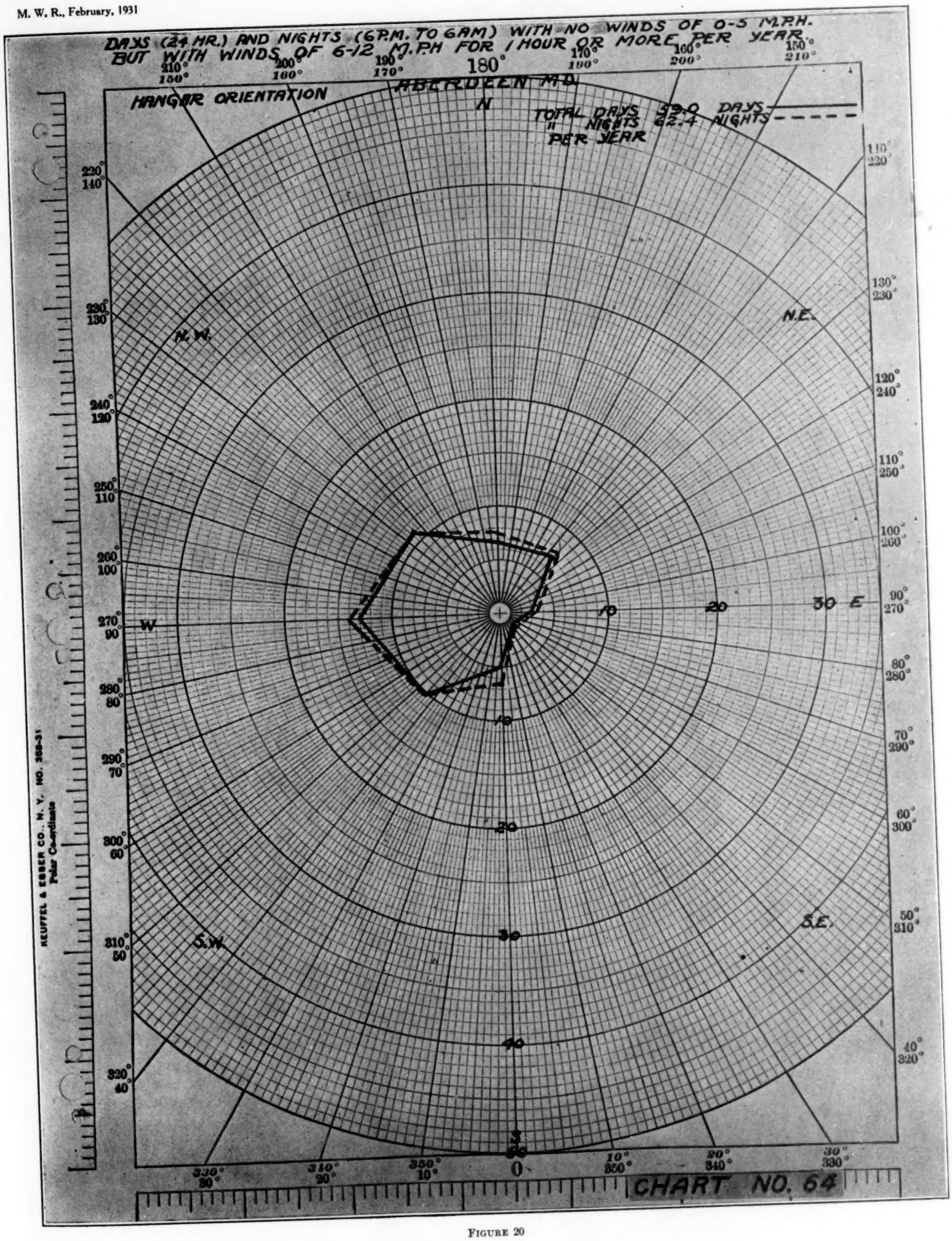

FIGURE 20

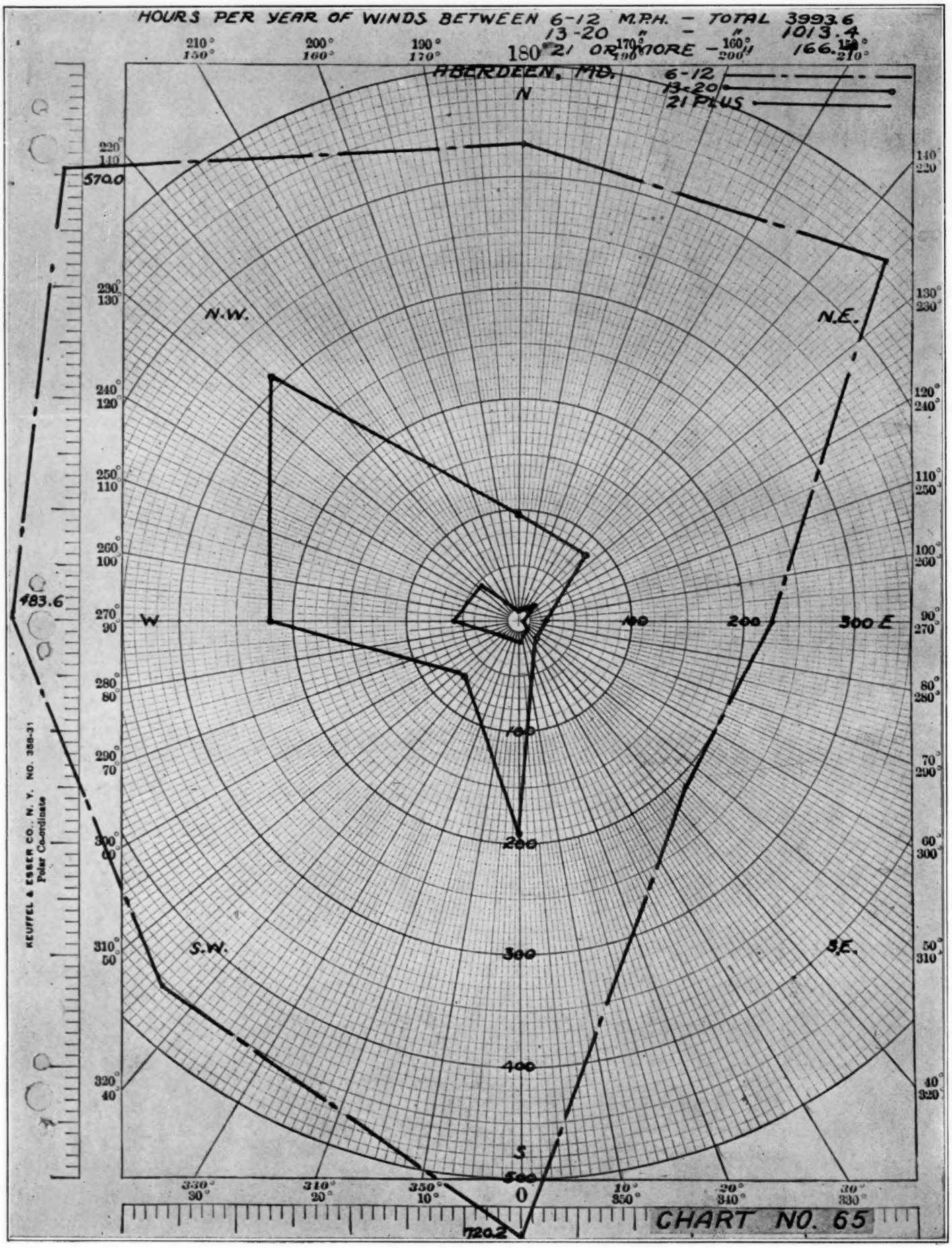
HOURS PER YEAR OF WINDS BETWEEN 6-12 M.P.H. — TOTAL 3993.6
13-20 " — " 1013.4
21 OR MORE — " 166.4
ABERDEEN, MD.
6-12
13-20
21 PLUS
N
N.E.
E
S.E.
S
S.W.
W
N.W.
100
200
300
400
500
720.2
483.6
57.0
CHART NO. 65
KEUFFEL & ESSER CO., N. Y. NO. 359-31
Polar Coordinate

FIGURE 21

NEW LIGHT ON THE BEGINNINGS OF THE WEATHER BUREAU FROM THE PAPERS OF INCREASE A. LAPHAM

By ERIC R. MILLER
[Weather Bureau, Madison, Wis.]

The papers of Increase A. Lapham, given to the Wisconsin Historical Society by his daughter, contain a great deal of important material for the history of meteorology. To understand how Lapham occupied an important place in this history it is necessary to briefly sketch his life and work.

Born at Palmyra, N. Y., in 1811, the son of a contractor on the Erie Canal, Lapham spent nearly half his life amidst the digging of canals and the building of locks. The strata exposed in cutting the canals, the minerals, shells, fossils, Indian remains, and the plant and animal life of the wild country became matters of prepossessing interest to him. Pursuit of this interest led him to read every scientific book and journal that he could lay hands on, and to correspond with men of science, seeking light on the problems that confronted him. Benjamin Silliman, founder of the American Journal of Science, took great interest in him, and published his first paper (1) written at the age of 16.

Beginning as rodman on the Welland Canal, Lapham entered the profession of civil engineer. On the Miami Canal he became assistant engineer under Byron Kilbourn who remained his lifelong friend. A shift of canal-building activity to the Ohio Valley placed Lapham on the staff of the Ohio State Board of Canal Commissioners, as assistant engineer at Portsmouth, afterwards as secretary with office in the capitol at Columbus where he urged upon the legislature (1835) the importance of a geological survey and was placed by the legislature on its committee and made a preliminary survey of the geological resources of Ohio (2, 3).

Political change abolished the canal board in 1836, and caused Lapham to emigrate to Milwaukee where he joined Kilbourn on the Milwaukee and Rock River Canal, and rose through the grades of engineer, chief engineer, to secretary before railway building ended the project in 1845. Surveying, reporting on mines and quarries, publishing maps and guidebooks afforded his livelihood, but he found time to devote to observing, collecting, classifying, and describing. In the 47 years from the publication of his first paper until his death in 1875, Lapham published 44 important papers, mostly in the transactions of learned societies in the Middle West. A survey of the Indian mounds of Wisconsin, financed by the American Antiquarian Society was published by the Smithsonian Institution (4).

Generosity in exchanging specimens brought Lapham an ever-widening circle of correspondents. Of names still well known his letter files include Asa Gray, John Torrey, W. S. Sullivant, George Englemann, W. J. and J. D. Hooker, Leo Lesquereux, Louis Agassiz, James Hall, Alexander Winchell, J. D. Dana, H. R. Schoolcraft, Joseph Henry, J. P. Espy, M. F. Maury, Lorin Blodget. Even Brigham Young wrote for seeds of grasses to plant in Utah. He was elected corresponding member of a long list of academies, ranging from the Royal Society of Northern Antiquaries of Copenhagen on the east to the California Academy of Sciences on the west. The honorary degree of LL.D. was bestowed by Amherst College in 1860, and that body of American "immortals" the American Philosophocal Society of Philadelphia elected him to membership in 1874 after he had become chief geologist of Wisconsin.

Civic, educational, and scientific organizations always claimed Lapham's enthusiastic support. He organized a lyceum at Portsmouth, in 1832, was member, curator of collections, and treasurer of the Historical and Philosophical Society of Ohio, and member of the Western Academy of Natural Science at Cincinnati in 1834 and 1835. At Milwaukee he was active in the County Agricultural Society (secretary, 1837), Lyceum (secretary, 1839), Library Association (director, 1847), Young Men's Association, Sons of Temperance. Of State societies he was active member of the Minnesota Historical Society (1851), Historical Society of Wisconsin (corresponding secretary 1851, life membership 1855), Academy of Natural Science of Chicago (chairman of geology, 1857), Iowa Historical Society (1857), Upper Mississippi Valley Historical Society (1863), Wisconsin Academy of Sciences, Arts, and Letters (one of the five founders, and first secretary, 1870). In 1847 the Milwaukee city council appointed Lapham to negotiate a loan for building schoolhouses, and he donated 13 acres for the high-school site. He was one of the founders of the Milwaukee Female Seminary (Milwaukee-Downer College) and in 1850 as president of the governing board presented diplomas to the first graduating class.

Meteorology seems to have first come to his attention in a letter from his brother Darius, in 1840, outlining Espy's theory of storms. This he gave to the Milwaukee Advertiser for publication, and brought the subject up for debate in the lyceum, with the result that he and Carl J. Lynde were deputed to make weather observations, a duty that they performed from December, 1840, to March, 1842. Espy himself sent Lapham blank forms and requested his cooperation in July, 1842, but Dr. E. S. Marsh was prevailed upon to undertake this work until he joined the rush to California in January, 1849. Lapham then acted as interim observer until 1853, when news arrived of the death of Marsh in the explosion of the boiler of the steamer *Louisiana* on which he was returning. Carl Winckler, a druggist then observed from 1853 to 1858. At the end of 1858, Captain Meade (afterward generalissimo at Gettysburg) was organizing a net of meteorological and hydrographic observers for the Lake Survey, and asked Lapham to undertake the work at Milwaukee. In performing this duty, from 1859 to 1872, Lapham prepared elaborate summaries of his own and his predecessors observations, working out hourly mean pressures and temperatures, 20-year daily means, etc. At the same time he cooperated with the local press, and with the State agricultural and horticultural societies, preparing climatological tables for all places in that State at which observations had been made. He had written articles on Wisconsin climate for periodicals like the Northwestern Journal of Education (pp. 117–120, 1850), the American Almanac (1852, pp. 102), Chicago Academy of Sciences (vol. 1, pt. 1, pp. 58–60).

Shipwrecks on the Great Lakes were a matter of grave concern to Lapham, hence when the reports of Espy, formulating the laws of storms were published, Lapham began agitating for their practical application. In January, 1850, his propaganda, supported by memorials from

the Milwaukee Board of Trade and the Wisconsin Agricultural Society, and a list that he prepared of the disasters on the Lakes in 1848 and 1849, induced the Wisconsin Legislature to consider a bill establishing a State weather service, with 29 stations, 1 in each county, after the Pennsylvania pattern, but with telegraphic reports to Milwaukee. After apparently favorable progress the bill failed to pass. In the hope of convincing doubting legislators Lapham, with the cooperation of Asa Horr, at Dubuque, timed the passage of barometric troughs across Wisconsin, and found that six to eight hours elapsed. These tests were made in 1853, and again in 1860–61. Starting of car-ferry service between Grand Haven and Milwaukee by the Detroit & Milwaukee Railway, in 1858, spurred Lapham to another effort in behalf of his favorite project. He wrote to C. J. Brydges (December 31, 1858), president of the railway, quoting Espy's results, and explaining the value of the warnings to the captains of the car ferry. Brydges refused to undertake weather reports on the ground that a cable across Lake Michigan would be required. Lapham then presented the project to Joseph Henry asking that the Smithsonian Institution supply barometers and wind vanes for reporting stations at Prairie du Chien and La Crosse, saying that the telegraph company would transmit the reports free of charge. Henry replied that his finances would permit him to offer nothing more than thermometers for the observers, and mentioned Maury's effort to establish a rival service. The Civil War made any further effort out of the question for the time, but in 1869 the success of Cleveland Abbe in enlisting the support of business men for a telegraphic weather service at Cincinnati encouraged Lapham to make another effort.

Cleveland Abbe (born 1839, died 1916), astronomer, trained by Brunnow at Ann Arbor, and by Struve at Poulkova, had been called in 1868 from the Naval Observatory at Washington to the post of director of the Cincinnati Astronomical Observatory. This observatory, founded in 1842 by Ormsby M. Mitchel, and supported in part by private subscription and in part by Mitchel's writings and lectures, had fallen into desuetude during the Civil War. Abbe threw himself with great enthusiasm into the rehabilitation of the observatory but quickly found both the building and the site unsuitable. A new site had been offered, and it was with the object of maintaining public interest and support pending collection of funds for a new building that Abbe turned to meteorology. In the end the delay proved fatal to Abbe's prospects. The supporters of the observatory became interested in founding the University of Cincinnati. The grounds of the old observatory, in which the Longworth family held a revisionary interest were sold for $50,000 and the money given to the university fund. Interest in the observatory temporarily fell off, and with it the income of the astronomer, so that by the end of 1870, Abbe, who had just married, was obliged to search for more lucrative work. The new site and the astronomical instruments were then turned over to the new university but astronomical work was not resumed until 1873.

The first communication from Abbe to Lapham was an invitation dated August 9, 1869, to attend a meeting to organize a meteorological association. This was followed on August 29, 1869, by a letter saying that the Chamber of Commerce of Cincinnati had requested Abbe to publish a daily weather bulletin, and asked on what terms Lapham would furnish reports from Milwaukee. Lapham induced the Milwaukee Chamber of Commerce to defray all expenses of reports from Milwaukee, but as Lapham lived too far from the telegraph office, Louis E. Levy was engaged to make the observations under Lapham's supervision. Abbe acknowledged this in the following letter:

CINCINNATI, *October 15, 1869.*

DEAR SIR: The many demands upon my time have forced me to delay writing you, as I would like to have done, to thank you for your kind interest in our observatory weather bulletin. This latter is meeting with much favor and I hope soon to be able to send copies of it to our correspondents.

At present I must confine this note to a short request that you will please instruct the gentleman who sends me his daily observations to send me only the 7 a. m. observation and to send it so early that I may be sure of getting it before 10:30 a. m. of the same day. It should, if possible be delivered to the telegraph operator before 9 a. m.

The messages that I have received contain the three observations of the day and are received at 10:30 a. m. of the following day at which hour I visit the telegraph office and compile the daily bulletin The observations of the previous day have then lost much of their interest.

I trust that it will not much add to the voluntary labors of your friend, my correspondent. If this early transmission be incompatible with his duties I will endeavor to secure the services of the manager of the telegraph office.

I am much indebted to you for a copy of your interesting article on the meteorology of Lake Michigan, etc., which I have perused with interest.

I have the honor to remain,
Very respectfully yours,
CLEVELAND ABBE.

Hon. I. A. LAPHAM.

P. S. Please begin each dispatch with the name of the day of the week on which the observation is made and request the writer to sign his name.

C. A.

One day in November, 1869, Lapham met E. D. Holton on the street and learned that he was going as delegate to the annual convention of the National Board of Trade (now Chamber of Commerce of the United States) at Richmond, Va. While talking with Holton, it occurred to Lapham to renew his efforts for a storm warning service for the Great Lakes. He explained the matter to Holton, and asked him to put the matter before the convention. Holton agreed, provided Lapham would prepare a formal resolution embodying his plan.

On December 1, Lapham wrote Abbe that "a friend will call the attention of the National Board of Trade to the importance of storm warnings." Lapham's resolution was introduced by Holton at Richmond on December 3 (**5**) was referred to the executive council, and reported out by Chairman Hazard with an added clause "to recommend to Congress to afford such aid to the different observatories of the country as will enable the astronomers in charge to give necessary time to the subject." Lapham afterwards surmised that this was written by the delegates from Cincinnati, of whom John A. Gano (president of the Cincinnati Chamber of Commerce) was nember of the executive council at Richmond. This episode of the Richmond convention was fruitless simply because the executive council did not meet again until March, 1870, to prepare the memorials of the convention for presentation to Congress (**6**, p. 6 and 12), by which time Congressman Paine, from Milwaukee, acting on other representations from Lapham had already procured the passage of the desired legislation. Holton's claim (**7**) that he immediately forwarded the resolution of the convention to Congressman Paine is belied by its absence from the memorials that Paine had printed in the Executive documents.

That Abbe was not aware of the Richmond resolution is indicated by the following contemporaneous letter:

CINCINNATI, *December 4.*

MY DEAR SIR: I am indebted to you for two highly esteemed letters with valuable inclosures. The former should have been answered long since but that my time has been so completely occu-

pied by the daily recurring duties of my position that all correspondence has been postponed now for the past five months.

I shall surely make an appropriate return for your very highly valued photograph as soon as I have some of my own taken.

Your essay on the meteorology of the lake country was too intimately connected with my own studies not to attract my immediate attention.

Although not professing to know much of meteorology yet I have undertaken the preparation of our daily weather bulletin as a means of starting what I esteem to be a highly important enterprise.

The three months' trial are not at an end and the chamber of commerce of this city who have liberally defrayed the incidental expenses of the same are now of the opinion that it is able to sustain itself (with the support of the daily press of this city).

Negotiations are now in progress which will doubtless lead to the call of an able meteoroligist to take charge of this matter and the attempt to forewarn important ports of approaching storms will be inaugurated and pushed systematically.

I hope that I shall thus in a few months be able to return to my proper study—astronomy—and to extend the labors of the observatory in that direction.

At present we are unable to do anything satisfactorily because of our ill-constructed building and exposed situation.

Your list of disasters on the Lakes is a sad picture and it should be the earnest endeavor of all scientists so to obtain that knowledge as to avert such calamities.

I return your barometric curve after having entered by date the observations made at this observatory during that time (recorded in local mean time), the comparison of the curve will have some interest to you. It is to be regretted that Thanksgiving Day somewhat interfered with the labors of myself and two faithful assistants.

With high respect I remain,

Very truly yours,

CLEVELAND ABBE.

Hon. I. A. LAPHAM.

Abbe gives the following history of the Cincinnati bulletin in his annual report as director of the Cincinnati observatory, dated June 4, 1870:

The bulletin began September 1, 1869, in a manuscript form. Since December 1, 1869, independent publication was discontinued and the bulletin only appeared in the morning papers. A daily compilation was undertaken two weeks ago (i. e. May 20, 1870) by the Western Union Telegraph Co. and will so continue thus relieving the observatory of all further responsibility.

Soon after Holton left for Richmond, Lapham mentioned his project for telegraphic storm warnings to Mr. C. W. Jenks, editor of the Bureau, a commercial journal published monthly at Chicago to which Lapham had contributed articles. Jenks asked Lapham to write an article on the subject. This appeared in the January, 1870, issue and contained the suggestion that the weather service should be established as a department of the Chicago Academy of Science (of which Lapham had been member, and chairman of geology, since its beginning). This reference to the academy has been misinterpreted by Abbe (8) and Weber (9). William Stimpson, president of the academy, received the suggestion cordially, writing Lapham, February 1, 1870, "we hope that such a bureau of the academy may be established and we are doing all we can toward it. May we hope that you will come to Chicago and take charge of it." The Chicago Tribune (January 8, 1870) ridiculed the proposal, saying:

The January number of the Bureau is out and as usual is devoted to questions of finance and commerce. A rather curious feature of this number is an article in favor of establishing a meteorological department in the Academy of Science. The article is accompanied by a map purporting to show the origin and progress of the storm of March 14–17, 1859, and that it might have been known on the Lakes a whole day before it reached there. It might be asked of what practical value such a department would prove it if takes 10 years to calculate the progress of a storm.

Jenks, editor of the Bureau, proposed a stock company with capital stock of $200,000, and asked Lapham to accept the presidency.

On December 8, 1869, the Milwaukee Sentinel published a list of 1,914 vessels, valued at $4,100,000, that had been lost on the Great Lakes in the year 1869, with loss of 209 lives of sailors and passengers. This reminded Lapham of his memorial to the legislature in 1850, so he prepared a formal memorial to Congress in the following terms:

Not only does the interest of commerce and navigation, but also that of humanity itself, demand that something be done, if possible, to prevent the fearful loss of life and property on our Great Lakes, such as has recently filled so many newspaper columns with their appalling details.

If we could have even a few hours' notice of the approach of the great storm that bring these calamities upon us, much of their mischief would be avoided. The endeavor to predict the occurrence of storms has been attempted in England, by the late Capt. Fitz Roy, and in France by Le Verrier, the astronomer, with what success will appear from the following extracts:

"On the 2d of December, 1863, I received two dispatches stating that a severe storm was about to traverse France" writes the president of the Toulon Chamber of Commerce to M. Le Verrier. "They were published and posted up immediately and the merchant vessels in the roadstead had time to provide and did provide against all risks. The maritime prefecture, on its behalf, directed all officers, who were on shore, to hasten on board their vessels. The storm burst forth with all its fury about 3.30 o'clock in the afternoon. The first telegram sent on the 2d confirming that of the day before, had therefore gained four hours time ahead of the storm, and everything was ready to meet the emergency. Thanks to the precautions thus taken there was no damage, no disaster to deplore."

The Genoese Journal of December 3, says that the "prediction telegraphed by the Paris observatory to turin, and immediately communicated to the ports on the western coast of Italy, on the 1st instant was fully realized. The first signs of the storm were felt yesterday about 7.30 p. m. During the night it raged furiously, but there appears nevertheless to have been no disastrous occurrence in our neighborhood. The commandant of the port had hastened to take all proper measures and we may be thankful for them."

Prof. J. P. Espy, in his second report on meteorology makes among many others the following generalizations from the observations made and collected up to the year 1850, the date of the report: "Storms in the United States travel from the west toward the east. They are accompanied with a depression of the barometer near the central line of the storm. They are generally of great length from north to south, and move side foremost toward the east. Their velocity is such that they travel from the Mississippi to the Connecticut River in about 24 hours and from thence to St. John's, Newfoundland, in nearly the same time, or 36 miles per hour, and the force of the wind is in proportion to the suddenness and greatness of the depression of the barometer."

Subsequent observations have fully confirmed the truthfulness of these important deductions, which may therefore be set down as established facts or principles in meteorological science. The storm of March 22, 1861, is known to have occupied eight hours in passing from Dubuque on the Mississippi to Milwaukee on Lake Michigan.

Now it is quite clear that if we could have the services of a competent meteorologist at some suitable place on the Lakes with the aid of a sufficient corps of observers with compared instruments at stations located every 200 or 300 miles toward the west, and the cooperation of the telegraph companies, the origin and progress of these great storms could be fully traced, their velocity and direction of motion ascertained, their destructive force and other characteristics noted—all in time to give warning of their probable effects upon the Lakes.

Doubtless there would be failures and mistakes made; and many experiments and repeated observations would be necessary before the system could be made to work with perfection. But is not the object sought of sufficient importance to justify such a sacrifice? If it should prove successful in even one case, it might be the means of saving property worth many times the cost of the experiment.

But how shall all this be accomplished and who will assume the burden of its cost. Perhaps the establishment of a meteorological department of the Chicago Academy of Sciences with a proper organization and a sufficient endowment would be the most likely to secure the desired results. The money should come from those most likely to be benefited.

This memorial, with clippings of the list of marine disasters, was forwarded in the following letter:

MILWAUKEE, WIS., *December 8, 1869.*

DEAR SIR: I take the liberty of calling your attention to the accompanying list of disasters to the commerce of our Great Lakes during the past year, and to ask whether its appalling magnitude

does not make it the duty of the Government to see whether anything can be done to prevent, at least, some portion of this sad loss in future.

Yours very truly,

I. A. LAPHAM.

Hon. H. E. PAINE, M. C.

By the rarest coincidence, Paine had studied under Elias Loomis at Western Reserve College, Ohio, when the latter was making his pioneer studies of storm structure and movement. Paine therefore fully realized the importance and the practicability of a storm-warning service. On December 14, 1869, he obtained permission to print the papers from Lapham as congressional documents (10) and two days later introduced his bill (H. R. 602) providing for the establishment of a storm-warning service. This was read twice and referred to the Committee on Commerce (11). As soon as copies of his bill and the Lapham memorial came from the Public Printer, Paine sent copies to the heads of the two existing weather services, Surgeon General J. K. Barnes and Joseph Henry, secretary of the Smithsonian Institution, and to his old professor, Elias Loomis, at Yale College. In an account of these incidents (12) Paine afterwards wrote "Immediately after the introduction of the measure, a gentleman called on me and introduced himself as Col. Albert Myer, Chief Signal Officer. He was greatly excited and expressed a most intense desire that the execution of the law might be intrusted to him." Paine gave Myer a copy of the bill and of the documents. Responses from Barnes, Henry, Loomis, and Myer were printed at Paine's request as congressional documents (13). For some reason, Paine rewrote his bill, and with the cooperation of Senator Henry Wilson (elected Vice President of the United States with Grant in 1872) introduced it as a joint resolution (H. R. 143) on February 2, 1870. This passed both houses, and was approved by the President in only one week. This speed not only anticipated the action of the executive council of the National Board of Trade on the Lapham resolution, but even the Committee of the New York Chamber of Commerce did not get around to recommend extension of the scope of the first Paine bill until March 17, 1870 (14) John D. Jones, who had proposed a commercial weather service in 1848 was member of this committee.

The rôle of Cleveland Abbe in these events is clearly shown by the following letter, the original of which like those previously quoted is in the collections of the Wisconsin Historical Society.

CINCINNATI OBSERVATORY, *January 7, 1870.*

DEAR SIR: I must write to express the pleasure experienced in realizing the energy with which you are pushing the matter of a telegraphic meteorological system of storm warnings.

My own labors in this field have been not perhaps so much for the good of the country and the advance of meteorology as for the sake of astronomy.

We can, I think, make no more progress in our knowledge of terrestrial and celestial refractions until we better understand the laws of distribution of heat and pressure in the atmosphere and our proposed system of signals coupled with a daily bulletin or chart will much help the study.

My additional incentive has been the desire to inform the community in general with the usefulness of the work carried on at observatories. To this end I have endeavored to expand the field of activity of the observatory so as to include meteorology, magnetism, geodesy, geography, and all other matters kindred with astronomy.

By pursuing this course it seems as though we might hope to place upon a sure foundation the establishment of a few good observatories which should combine the usefulness of Greenwich and the science of Poulkova.

I trust that in this view you will coincide or at least that it will not be opposed to the principle that may have guided you. Astronomy especially has suffered in this country from dissensions and the observatories have been weak and poorly appreciated. We must seek to secure the support of the people by demonstrating our usefulness.

I have in the Smithsonian report for 1867 shown the course pursued by Struve and its results. He may well be accepted as a model in this respect.

I write with the more feeling because I have noticed the introduction of a bill in the United States Senate recommending the appropriation of money to the Army for the purpose of carrying on the system of storm warnings.

Now these warnings ought to be based upon observations made by the intelligent telegraph operators or managers of offices or other employees. The meteorological observations of the Army have generally proved themselves very unreliable and are certainly no better than those that the telegraph operators could easily make.

It would, I think, have been wiser if the bill had recommended that Congress appoint a committee of three (Henry, Coffin, and a naval or Army officer) to report some plan of action.

And I am specially of opinion that the money expended would do more toward effecting good results if it goes through the hands of meteorologists than through the hands of Army officers.

It would be a pity to see the country saddled with an inefficient meteorological office as it has already enough to do to carry on the naval observatory with its present objectionable system of management. Every such onus is a hindrance to the progress of science in this country.

I presume, however, that we shall both be able to unite upon some plan that will prove feasible.

I beg to thank you again for the copy of the Bureau containing the map of the storm of 1859, March 14. The daily weather bulletin that I have been publishing stops temporarily but will be resumed. I have sent a short notice of it to the Bureau.

Very respectfully yours,

CLEVELAND ABBE.

Hon. I. A. LAPHAM.

Paine afterwards wrote that his "reason for requiring the Secretary of War to execute the law was this: It seemed to me at the outset, military discipline would probably secure the greatest promptness, regularity, and accuracy in the required observations." The economy of having the work performed by the Army, whereby all expenses for pay, subsistence, quarters, and travel of officers and soldiers were borne by the usual appropriation for the Army, and the only additional expense was for telegraph tolls, stationery, instruments, pay of civilians, etc., doubtless facilitated the passage of the act. The initial appropriations were $15,000 for the remainder of the fiscal year ending June 30, 1870, $50,000 for the next fiscal year.

The Secretary of War promptly assigned the meteorological duties to the Chief Signal Officer of the Army, Brevet Brig. Gen. Albert J. Myer, who christened the new activity "the Division of Telegrams and Reports for the Benefit of Commerce." General Myer had entered the Army in 1854 as assistant surgeon. While serving with troops in New Mexico he observed Comanche Indians signaling with their lances, and devised therefrom the now familiar code of wigwag signals with flags and torches to replace the couriers then in vogue as the sole means of military communication. In 1860 Myer was appointed signal officer of the Army to develop his system. The Civil War brought a huge expansion of the Signal Corps, as part of the volunteer army. In 1863 Myer became involved in controversy with the Superintendent of military telegraph over control of field telegraph lines, with the result that he offended Secretary Stanton, was relieved from duty and sent to Cairo awaiting orders which never came. His appointment ran out July, 1864, and he was out of the Army for nearly three years. Lieutenant Colonel Nicodemus succeeded to Myer's place, and his quarrel, with the result that he was summarily dismissed from the Army December 26, 1864. Maj. B. F. Fisher, next in command, more diplomatic, carried on and was nominated, February 13, 1866, by President Johnson to be Chief Signal Officer, and was confirmed by the Senate. Myer's friends then

melodramatically came to the rescue, induced the Senate to recall Fischer's confirmation, and in 1867 procured the appointment of Myer with pay of colonel, from July 28, 1866, rank of Brevet brigadier general, and commendation for gallant and meritorious conduct in organizing, instructing, and commanding the Signal Corps. He had previously won congressional commendation for bravery in action. However, the Signal Corps had been mustered out with the volunteer army in 1865, and the Army reorganization act of 1866 had specified that under the Chief Signal Officer the duties of signaling should be performed by not to exceed 6 officers and 100 men, detailed from the Corps of Engineers. It is on this account that Myer was spoken of as a bureau chief without a bureau. It also resulted in his bureau being referred to by a variety of names, Signal Service, Signal Corps, Signal Office, Signal Detachment, Signal Force, Signal Bureau. The estimates for 1870–71 (15) for his establishment consist of the following items:

	Pay	Subsistence	Clothing	Total
Chief signal officer	$1,320	$657		$1,977
2 servants, enlisted	384	219	$156	759
2 clerks, class 2	2,800			2,800
Total				5,536

His troops had been practicing with salvaged war material in the abandoned forts, Greble and Whipple (the latter now Fort Myer), but the estimates just mentioned contain the first postwar request for funds for the purchase and repair of electric telegraph and signal equipment for the Army. Myer asked $10,000 but the Secretary reduced it to $5,000 over Myer's protest, which was printed in the estimates.

Myer's excitement, mentioned by Paine, can be set down to a just appreciation of the possibility of directing another growing institution like the war-time development of the Signal Corps.

Myer's first-meteorological report for 1870 shows him busy enlisting and training observers, buying instruments, negotiating with telegraph companies, and renting offices. He sought advice from G. W. Hough, of the New York Meteorological Service, and from Balfour Stewart at Kew Observatory, also from the Smithsonian Institution, Coast Survey, Naval Observatory, Commissioner of Agriculture, Surgeon General, and the Cincinnati Observatory.

Apparently, Myer hoped to get along without forecasters, for he writes (16):

> The publication of official deductions or forecasts to be had from the mass of reports received at different centers involves so much of responsibility, that, while it has been considered, the office has not been willing to enter upon it, until it shall have practically tested the promptness with which reports will be received, and the facts as to the approach and force of storms which synchronous reports following each other in close succession will announce without any effort of anticipation.
>
> It has been considered wise by this office not to attempt more than this at the outset.

However, the new service was not ready to begin telegraphic reports until November 1, 1870, in the midst of the season of storms on the Great Lakes. Under these conditions Myer must have suddenly changed his mind, for he telegraphed Lapham to meet him at Chicago on November 8, 1870. There he tendered and Lapham accepted appointment as Assistant to the Chief Signal Officer at a salary of $167 per month, to supervise the signal service on the Lakes. Appointment and orders were written out in Myer's own handwriting and are in Lapham's papers. Myer must have felt that the situation admitted no delay for Lapham issued the first storm warning on the day of his appointment. The selection of Lapham may have been influenced by Paine. The Lapham papers contain a note dated October 13, 1870, from Paine, then in Milwaukee, asking Lapham to call at his office, as he wished to communicate with him about storms.

Lapham necessarily began forecasting with no previous experience, and with only what information could be gleaned from the publications of Redfield and Espy, Loomis's Meteorology (of these Lapham's personal copies, are now in the library of the University of Wisconsin). It is worthy of note that Lapham used isobars and isotherms on his forecast maps at Chicago (17), while the Washington forecast maps, begun January, 1871, imitated the Cincinnati bulletin in omitting these lines. The difficulties of forecasting must have seemed overwhelming at times. On November 23, 1870, Lapham left suddenly for Milwaukee asking that all telegrams be sent to him there, explaining that it was necessary for him to have access to his library. Captain Pyne, acting Signal Officer, replied that the post of assistant could not be changed to Milwaukee, asked Lapham to move his books to Chicago, and expressed the hope that no detriment to the service had occurred on account of Lapham's absence. The complete net of reporting stations numbered only 25, and on one occasion a storm reduced the number received to four. The observer sergeants had been supplied Guyot's Tables and left to their own devices to reduce the barometer to sea level at each observation. The results were so chaotic that Lapham had to set to work in the midst of forecasting to prepare uniform reduction tables for each station. Meantime, there were other irritations. On December 20, 1870, Capt. Garrick Mallery called attention to an error in his official signature The title "Assistant Chief Signal Officer" which Lapham has used was "liable to misconception" and "might cause criticism in the War Department." Lapham recommended appointment of his son Henry as observer at Milwaukee, and was asked by Mallery if he wished Henry to enlist in the Signal Corps and be assigned as observer sergeant to Milwaukee. The Laphams being Quakers this suggestion was not available. Then, Lapham's many business interests at Milwaukee left at loose ends by his sudden appointment, demanded his attention so that he was obliged to ask (December 26, 1870) to be allowed 2 days a week at Milwaukee, and offered to resign his post if it could not be arranged. Then his friend Kilbourn died, naming him executor. Lapham took leave of absence in January, 1871, to go to Florida to look after lands owned by Kilbourn, and on his way back visited Washington, whence he wrote his daughter:

> WASHINGTON, D. C., *February 3, 1871.*
>
> DEAR JULIA: I dined last evening with General Myer at his home on I Street. Have arranged matters satisfactorily—am not to be ordered to Chicago any more.

This arrangement, however ideal for Lapham, could not have been satisfactory to General Myer, whose appropriation of $50,000 for the year 1870–71, $102,451 for 1871–2, was quickly swallowed by rapidly increasing demands for service to the public. However, Lapham was allowed to live at Milwaukee and to devote himself to the leisurely preparation of a report on atmospheric electricity, to collection of statistics on the frequency of storms and of the disasters on the Great Lakes. The great fires of October 8, 1871, of which the Chicago fire is the best known, while the Peshtigo fire in the Wisconsin

forest destroyed many more lives, also formed the subject of an official report from Lapham's pen. He visited the observer at Chicago the day after the fire, and finding that his reduction tables had burned, supplied new ones from his own copy. The termination of this arrangement came in the following form:

WASHINGTON, D. C., *May 11, 1872.*

Dr. I. A. LAPHAM,
Milwaukee, Wisconsin.

DEAR SIR: I am directed to inform you of the limited amount of money at the disposal of this office for the current year and the consequent necessity for the reduction of its working expenses. The arrangement by which your valuable services have been secured as Assistant to the Chief Signal Officer will terminate at the close of the present month.

It is hoped that the office will be in sufficient funds by that date to liquidate your account in full.

Respectfully,

H. W. HOWGATE,
Captain, and acting Signal Officer.

Of Lapham's later career it will suffice to mention that as chief geologist (April 10, 1873, to February 16, 1875) he organized and energetically directed the Wisconsin Geological Survey. He was beginning an investigation of temperatures and other conditions in the inland lakes of Wisconsin, with reference to fish production, when he died of heart failure while in a boat on Lake Oconomowoc, September 14, 1875.

Beginning January, 1871, Myer organized at Washington a corps of forecasters consisting of two civilians, Cleveland Abbe and Thompson B. Maury, and one officer, Lieut. A. W. Greely, and made them responsible for forecasting for the entire country. Maury afterwards joined the staff of James Gordon Bennett's New York Herald, for which he wrote a daily column of weather information published on the editorial page under the unique title "Personal Intelligence." Greely led the tragic *Lady Franklin Bay* Arctic expedition of 1881–1883, one of the two expeditions for meteorological observations that Myer had undertaken as America's share in an international attack on the problems of Arctic meteorology. Greely succeeded to the place of Chief Signal Officer, March 3, 1887, and remained in command of the Signal Corps when the Weather Bureau was separated in 1891. Cleveland Abbe occupied throughout his life the position of dean of the scientific staff of the National Meteorological Service and is probably best known as editor of the MONTHLY WEATHER REVIEW, and of three volumes of papers on the mechanics of the earth's atmosphere published by the Smithsonian Institution.

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12. Letter from H. E. Paine dated October 8, 1903, to Mr. Duane Mowry, Milwaukee, Wis., quoted by permission of Mr. Mowry.
13. Cong. Doc., Ser. No. 1416, Doc. 10, pt. 2.
14. H. R. Misc. Doc. No. 105, 41st Cong., 2d sess., vol. 3.
15. Estimates of Appropriations for the Army for 1870–71, 41st Cong., 2d sess., Ex Doc. No. 5.
16. Annual Report of the Chief Signal Officer. 1870, p. 11.
17. Annual Report of the Chief Signal Officer, 1871, Paper No. 1½, beginning p. 167.

ANTARCTIC METEOROLOGY

By HENRY T. HARRISON

[Weather Bureau, Cleveland, Ohio]

The title "Antarctic Meteorology" may seem misleading and rather presumptious. To even begin to cover so vast a subject in a limited paper is of course out of the question. However, it is the aim here to present (1) only the general features of prevailing conditions, as now known, existing over the continent as a whole, and (2) to describe in detail some of the results of a 15 months series of observations made in one locality.

It appears to be fairly well established now that Antarctica is in the waning stages of one of the severest ice ages ever known. Save for bare rocky outcrops and bare sharp peaks the entire continent lies buried beneath the accumulation of centuries of snow and ice ranging upward to an estimated depth of several thousand feet on the polar plateau itself. Surrounded on all sides by the comparative warmth of ocean water, the cold continental air is constantly being mixed with violently opposed air masses from over the seas. Acting as a huge refrigerator the continental ice cap not only produces a steep temperature gradient in winter but maintains it to a lesser degree even during the short summer season. Add to this turbulent influence the typical glacial action of producing local but violent "fall" winds and we have the basic reasons for the unusual atmospheric activity over most of Antarctica, the stormiest area in the world. Sir Douglas Mawson aptly named it "The Home of the Blizzard." At his winter base in Adelie Land south of Australia hurricane winds were of almost daily occurrence and occasional gusts neared a velocity of 200 miles per hour.[1] Captain Scott and Sir Ernest Shackelton experienced very nearly the same winds although interspersed with a far greater proportion of calms at McMurdo Sound near the western edge of the Ross Sea.[2] Little America and the Bay of Whales region are comparatively free from violent hurricane winds although just 100 miles to the east at the foot of the Rockefeller Mountains the geological party of the Byrd Expedition experienced one storm during which the wind reached an estimated velocity of 150 miles per hour. The oceans surrounding Antarctica are generally recognized as being the stormiest waters in the world. The extreme local nature of many of the storms has been proven time and again. After the aforementioned Rockefeller Mountain hurricane there were evidences that little more than a moderate gale had prevailed just a few miles away while, at Little America, the same storm produced a wind of only 50 miles per hour (22.4 m. p. s.). Mawson and his party in Adelie Land found the almost unbe-

[1] Mawson, Douglas. The Home of the Blizzard.
[2] Shackelton, Ernest Henry. Scott's Last Expedition. London.

lievable combination of a strong gale and a light breeze prevailing side by side within the limits of a few miles.[1]

At widely scattered intervals but especially during winter great cyclonic storms develop somewhere near the rim of the continent and are attended by severe blizzards over a wide area. Definite paths of these cyclones remain unknown although one well defined track appears to lie along or near the Antarctic Circle with general movement from west to east. Professor Hobbs holds to the theory that a great glacial anticyclone covers the interior of the continent and this view is shared by others although as yet no definite conclusions may safely be drawn because of the scarcity of available data. Only scattered and irregular observations have been made on the polar plateau during two of the summer months and winter conditions there are absolutely unknown. Another theoretical distribution of pressure places an anticyclone over the polar plateau and, surrounding it, a series of cyclone centers which move in unbroken succession from west to east along the outer edge of the continent. The normal drain of air is from the pole outward toward the sea at the surface but, due to deflection by the earth's rotation, winds become easterly or southeasterly near the oceans. Theoretically this outpouring of air at the surface would be offset by an inflow at higher levels of air from lower latitudes. Pilot-balloon soundings bear out this theory for the most part although many instances have occurred where winds were from the south up to altitudes of 4 miles (5,000 meters) and occasionally even into the stratosphere.

Due to excessive cooling near the ice surfaces sharp inversions of temperature prevail at low levels aloft during periods of calms or light winds; hence the blizzard winds, which actually blow from the colder interior, are almost invariably attended by rapidly rising temperatures at the surface as a result of the mixing of the two layers of air. Evidences also show that many of the blizzards, expecially those in the Ross Sea region, are simply relief valves by means of which enormous masses of cold air which pile up in the interior are dumped over the sea, somewhat in the manner of the working of a hydraulic ram. During the expeditions of Scott, Shackelton, and Byrd it was noted that any protracted period of extreme cold on the Ross Barrier, or Ice Shelf as it is now known, was invariably followed by a severe blizzard at the edge of the Ross Sea. Once an initial release was given to this sluggish mass of dammed up air—and this could be accounted for by a weakening of pressure in the Ross Sea—a violent outpouring would result for a day or two until equilibrium was once again established. Simpson [2] points out that a semipermanent area of relatively low pressure prevails over the Ross Sea as a result of the steep temperature gradient maintained in that region and that even a slight strengthening of the pressure gradient would be sufficient to supply the initial energy for the release of a blizzard.

Little America was the base camp of the Byrd Antarctic expedition from December, 1928, until February, 1930, and was established on slightly rolling slopes of the Ross Barrier at the Bay of Whales in the southeastern corner of the Ross Sea. The ice shelf in this region is floating in salt water with the nearest visible land and also the nearest known land lying 100 miles to the eastward. Pilot-balloon soundings and detailed surface observations were made daily over this 14-month period while soundings of the upper air by means of kites were made during the final season.

A smooth recording of data was beset with many difficulties, most of which could be traced to the weather itself, wind and cold. Because of their relative importance the pilot-balloon soundings were begun back in the early stages of the camp during the bustling days of unloading, sledging and snow-shoveling. At that time everyone was working from 12 to 15 hours each day in an effort to get the camp firmly established before winter set in, yet sufficient spare time was found each day to make at least one observation of the upper air currents. The balloons were inflated inside a tent and the readings made with a theodolite placed on the surface of the barrier, exposed to wind and cold. A succession of blizzards in February and March kept the instrument snowed under constantly so that it was necessary to shovel it out before each observation. Toward the end of April, however, attention was given to the building of a permanent shelter and stand adjoining the vestibule of the administration building with a telephone connection with the scientific room inside the house, thus doing away with the necessity of recording data outside in the cold. Because of the danger from fire inside the house the balloons were inflated with hydrogen in the tunnel exit of the house where the temperature averaged 40° below zero and this fact alone was the cause of more than one ruffled disposition. As the dark winter came on and the temperature dropped still further the lens and eye-piece of the theodolite were subjected to thick accumulations of rime frost until it became necessary to scrape off these coatings with a small stick every minute or so during observations in order to avoid losing sight of the balloon. Occasionally frost formed on the inside of the lens and whenever this happened the instrument had to be taken inside the house and thoroughly "baked out" over the stove. The small paper lanterns used in the night work were another source of worry. Unless well heated beforehand the tallow candles would refuse to burn properly in the cold and frequently went out entirely after the balloon was released. On one occasion five balloons were released before one continued to burn properly; consequently there was more than one reason for rejoicing when the sun returned to Little America in August and the lanterns and lights could be discarded. After a suitable combination of headgear, footgear and gloves had been worked out by experiment little discomfort was experienced in observing the balloons during the coldest weather of mid-winter when the temperature sometimes fell as low as −70° F. (−57° C.) Four hundred and fifteen soundings were made during the 14 months to an average altitude of almost 3 miles (4,500 meters). Curiously enough these observations furnished practically the only basis for making predictions of coming conditions for flight and camp activities. Generally speaking a deep southerly current aloft attended or preceded settled clear conditions and good visibility whereas northerly winds aloft were nearly always associated with thick overcast skies and low visibility. Attempts to interpolate general pressure distribution from local wind and barometric changes were so disappointing that nearly all forecasts were made on the basis of the prevailing upper winds and the assumption of their importation as air masses of varying degrees of temperature and moisture.

The kite work received an early setback when a large crate of parts was lost during one of the blizzards which swept over the camp in March. Replacement was impossible at that time and so it was late in the winter before enough spare parts could be made up to permit assemblage of the kites. For this purpose construction was begun on a large house of snow blocks with one end partitioned

[1] Mawson, Douglas. The Home of the Blizzard.
[2] Shackelton, Ernest Henry. Scott's Last Expedition. London.

off into a work room and the remainder serving as storage space. Interrupted by a 50-mile blizzard which blew down three of the main walls in a mass of ruin, the work was finally completed, the house roofed over with canvas supported by bamboos and a small blubber stove constructed for heating the work room. On a cold day outside the stove would raise the temperature inside the house to about 0° F. (−17.8° C.), just enough to allow bare handed work on the joints and wrappings of the kites. It was in this manner that these structures, of the Marvin-Hargraves cellular type, were set up and made ready for service. The first flight was begun on a particularly cold and disagreeable day in September when working conditions outside were anything but pleasant. After four men had been frostbitten about the hands and face before the flight was finished there was nothing to do but postpone further action until the arrival of more moderate weather. Flights were made with fair regularity during the next three months but were limited in altitude due to failure of the motor driven reel and the necessity of resorting to hand reeling. The prevalence of low stratus clouds during a majority of the flights resulted in quite heavy deposits of hard rime upon the kites and wire, great enough on several occasions to force the kites down, to the surface. These deposits, while not strictly ice were layers of very closely packed frost crystals which built up on all windward surfaces of kites and wire sometimes to a thickness of 3 inches (7.7 centimeters) during the course of several hours exposure in the subcooled clouds. The fact that rime formed on every occasion when kites entered clouds is significant in that it points out a very evident danger which attends the use of dirigibles in polar latitudes. Aeroplane flights at Little America were made only when the sky was clear and so no opportunities were offered for the study of ice formation on heavier-than-air craft.

Fog, while infrequent, was important from the point of view of demonstrating that water vapor can exist in a subcooled state in nature at temperatures far below the freezing point. On one occasion fog formed at −30° F. (34.4° C.) which was dense enough to obscure objects at a distance of 1,000 feet (300 meters). Lighter fogs were observed at −40° F. (−40° C.) but below this point the water vapor ordinarily gave away to a haze of floating ice crystals. Subcooled fog was also attended by a formation of rime. On June 11 a combination of fog and misting rain at a temperature of 5° F. (−15° C.) resulted in the formation of a fringe of rime as much as 4 inches (10.2 centimeters) in thickness on the windward surfaces of all exposed objects. The mist was first attended by a thin coating of glaze before rime began to form. This fall of rain in the dead of winter implies that an enormous temperature inversion existed somewhere above the base of the stratus clouds, a fact which can be explained by the prevalance of northerly winds aloft at the time. These winds were warmed by passage over the open water of the Ross Sea and possibly originated as far north as the Pacific Ocean. Precipitation in the form of snow was almost impossible to measure due to the heavy drift which accompanied most falls. Careful estimates, however, placed the annual snowfall at 103 inches (262 centimeters) which is in fair agreement with figures reported in the McMurdo Sound section. Sleet was unknown at Little America.

Cloudiness and relative humidity averaged high whenever the Ross Sea was open which is to say during most of the year. The two forms of overcast sky, peculiar to polar regions, "ice blink" and "water sky," were of frequent occurrence. The former is the milky, suffused glow upon clouds over snow and ice and the latter the pronounced dark reflection upon clouds over water. Standing on the barrier and looking to the north the sky presented a dark threatening appearance while overhead the sheet of stratus cloud was simply a milky gray blur devoid of all form. On days of this type the outlook was gloomy and discouraging indeed. No horizon was visible except to the north, a murky haze filled the air and, in the lack of contrasting shadows, it was impossible to distinguish any form in the snow at one's feet. Walking about on the rough snow one not only had difficulty maintaining a balance on the uneven surface but the strain on the eyes was often greater than that during the glare of bright sunlight. Ordinarily the line between the water sky and the ice blink was so marked that the edge of the barrier was perfectly outlined on the cloud layer above. Whenever scattered ice floes invaded areas of open water a mottled reflection upon the clouds resulted. In marked contrast to these dull depressing days the sky was often beautifully clear and presented a wide range of colors and delicate tints when the sum was low. Brilliant solar and lunar halos, parhelia, coronæ, the aurora and weird mirage effects—all of these played their part in breaking up the monotony of an everlasting white landscape.

The thermograph and hygrograph, self-recording instruments in the shelter outside, furnished a disagreeable duty once each week when the record sheets were changed. Both instruments were carried inside a tunnel where the temperature was nearly that of the outside air but with the advantage of being protected from the wind. Silk gloves worn during this operation furnished little protection for the hands at −50° F. (−45° C.) but prevented an actual contact with the cold metal of the clocks which would freeze bare finger tips instantly. The clocks themselves behaved beautifully in the cold weather after all trace of oil had been removed from the works with ether. The thermograph did stop when the temperature first touched −70° F. (−57° C.) but after a few minor adjustments were made no more trouble was had with either clock. The fine powdery drift of the blizzard was extremely troublesome through its action of sifting through minute cracks and blocking all movement of the pens. It also built up around the cogwheels with enough pressure to force the clocks off their bases at times. Almost constant attention had to be given to the instruments during the more severe blizzards. The anemometer also suffered in the cold due to an unequal contraction of the brass and steel parts and to the hard gritty layers of rime which formed on the cups. In spite of all of these little handicaps the instruments functioned as well as could be expected under the severe conditions and the records on the whole were consistent and trustworthy.

The severity of the Antarctic cold needs little discussion here. Any climate which can and does produce subzero temperatures (F.) every month in the year is truly frigid and when it combines strong winds with the cold as it often does life in the open is unpleasant indeed. The winter temperatures at Little America were not as severe as those sometimes recorded in the interior of Northern Siberia but the average temperature for the calendar year of −12.7° F. (−24.8° C.) was the lowest ever recorded over a similar period anywhere.[3] The lowest figure during the year was −72.4° F. (−57.8° C.) but a far more severe condition than this prevailed in July when a combination of a 25-mile (11.2 m. p. s.) wind and a temperature of −64° F. (−53.3° C.) was

[3] According to G. C. Simpson (*see* British Antarctic Expedition, 1910-1913, Vol. 1, Calcutta, 1919, page 91, Table 52) Framheim had a mean temperature for one year of −14.4 F., two months being interpolated.—EDITOR.

experienced. Kerosene lanterns froze up at −55° F. (−48° C.) and dry-cell flashlights were rendered useless also. Self-generating dynamo flashlights furnished the only source of light for outside use during the severe cold weather.

In conclusion it may be well to emphasize the fact that there is still an enormous field for meteorological research in Antarctica. Professor Hobbs has long pointed out the great value which would accrue from a year's observations on the polar plateau; such work would be possible although attended with extreme difficulties and hardships to the personnel involved. Simultaneous records at a number of points over the continent are also needed before a really comprehensive and intelligent study may be made of the laws which govern atmospheric action in the southern latitudes. Each expedition has added a bit more to this knowledge yet the field of operations of one or two isolated parties has necessarily been limited. The extent and rapidity of future research hinges, as heretofore, upon the generosity of the people and of organizations in offering financial support for expeditions.

REPORT OF THE STREAM-FLOW PREDICTION SUBCOMMITTEE[1]

By A. STREIFF, Consulting Engineer

[Jackson, Mich.]

The past year was characterized by a greatly increased universal interest in the possibilities of estimating stream flow, which previously has been and, in many professional and scientific quarters, still is regarded as being wholly a fortuitous sequence. During the past decade this viewpoint had gradually undergone a radical change, until to-day many earnest investigators recognize the presence of definite systematic elements in stream flow which permit conclusions to be drawn as to future run-off well in advance of occurrence.

PAST METHODS OF PREDICTION

In the planning of hydraulic projects, the manner of estimating future discharge quantities in the past has rested on a rather questionable basis, untenable on scientific grounds, and dictated by necessity rather than secure, basic knowledge. If stream flow is to be regarded as wholly fortuitous sequence, then the theory of probability is directly applicable to the estimate of future performance. Much has been theorized on future probability (probability a priori) based on past performance or experience (probability a posteriori) or so-called empirical determination of probability. It is a well-established fact that only a voluminous series of data can furnish a secure basis for future expectation. Such data must, moreover, be wholly freed from systematic sequences.

Instead of thousands of observations, hydraulic engineers usually have at their disposal only a few records covering not more than 10 to 50 years. It is evident that 50 dice throws will not give the same average as several thousand, and if systematic changes are introduced, such as changing the throw, the dice, etc., no reliable estimate of future averages based on previous performance is possible. Yet, this is the meager basis on which all hydraulic projects hitherto have been based. The future is held to have the same average, as well as limits of variation, as the past records indicate.

NEW METHODS OF PREDICTION

Certain it is, that stream flow records never repeat themselves, and ceaseless fluctuations exist, continually moving to higher and lower levels apparently in often recognizable systematic sequences. In Europe these have been studied and applied by Dr. Axel Wallen (Twelve Years of Long Distance Prognostication of Rainfall and Waterlevels, Annals der Hydr. und Maritim. Meteorology, September 1926, pp. 89–92), director of the hydrographic service in Sweden. Here, too, much research has been applied to finding a better way of estimating future stream flow. It is the near future which is of the greatest importance in hydraulic power projects, and this may be radically different from the immediate past; enough to create the difference between earned or not earned interest on outstanding bonds.

UTILITY OF PREDICTIONS

Experience of the past 10 years indicates that public utilities which derive their power supply in whole or in part from hydroelectric plants can apply these studies profitably to the appraisal of their future power supply. It appears that for the Great Lakes division it is quite possible to estimate hydraulic power output a year in advance to within 5 per cent. The general trend can be forecast for several years to follow, and thereby the steam power and coal supply requirements can be budgeted more accurately. No errors need be made as by one utility, which constructed an expensive booster pump installation for their circulating water just in advance of the rise in levels of the Great Lakes, or by another in the Great Lakes region, which hurriedly installed expensive additional boiler capacity to take care of threatening shortage just in advance of a rising hydraulic power output.

STREAM FLOW IN GREAT LAKES REGION

The Great Lakes region appears to be distinguished by a singularly regular multiannual sequence of stream flow, which enables close estimates of water power. Naturally such estimates are of greater value, the greater the amount of available storage. Without storage the annual (seasonal) variation determines the requirements of steam power; peak capacity is not affected by a variation of the annual mean, although even in such cases the annual coal supply is still subject to calculation in advance. Members of the Great Lakes division are enabled to utilize the knowledge of these systematic sequences of stream flow in the Great Lakes region to the extent above indicated.

The discovery of this regular cycle in stream flow is due to the hydrologist, Robert E. Horton (United States

[1] Extracted from the 1929-30 Report Hydraulic Power Committee, Engineering Section, National Electric Light Association, Great Lakes division. Presented at the tenth annual convention, French Lick, Ind., Sept. 25-27, 1930.

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Geological Survey Water Supply Paper No. 30). Since 1875 the cycle has faithfully recurred 10 times. At present a minimum is approached which will occur in 1931. A further maximum will occur in 1935, and a high maximum in 1940. The hydroelectric companies in the Great Lakes region will profitably note that next year will be a poor water year, and their hydro output will compare with the previous low around 1925.

On the other hand, abundant hydro output will be available in the Great Lakes region around 1934–1936.

STREAM FLOW IN MICHIGAN

For Michigan the graph shown in Figure 1 is illuminating. This graph represents the flow of the Muskegon River in Michigan. It may be seen that the relation with the maxima and minima of the Wolf numbers is striking. This graph was prepared in 1928 and first published in the periodical Power of April, 1929. The dotted line shown thereon is the probable extension of the annual mean stream flow as it appeared to the chairman of this subcommittee in the year 1928. The dotted line drops sharply, indicating dry years in 1930 and 1931. The present drought fully supports the estimate made two years ago. The estimates of power output for the Consumers Power Co. have checked as follows: For 1928, error 5 per cent; for 1929, error 2 per cent; for 1930 the first half of the year exactly corresponded with the estimate.

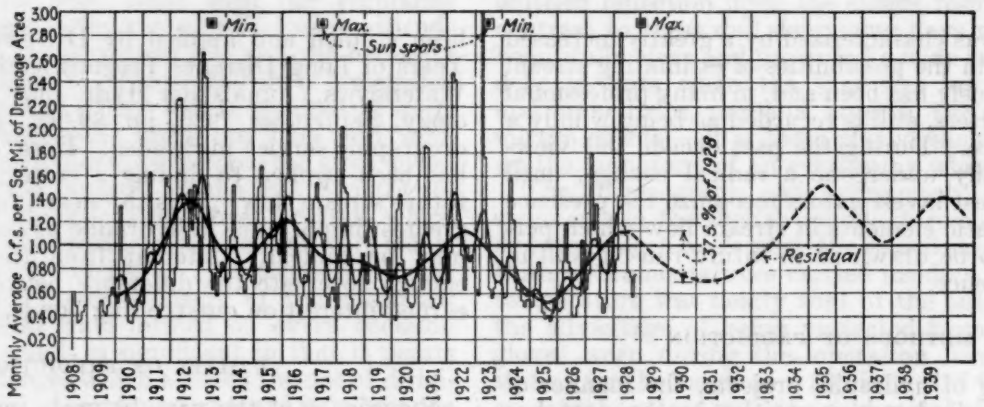

FIGURE 1.—Stream-flow prediction for Muskegon River, Mich.

It should be mentioned that the lower peninsula of Michigan has, on account of its heavy cover of glacial drift, a very great volume of ground storage, which favors the exact realization of these estimates. Next year a minimum output of hydro in Michigan will occur, the deficiency being as high as 37.5 per cent of the 1928 hydro output.

In a personal letter to the editor, Mr. Streiff comments on the methods of stream-flow prediction as follows:

JACKSON, MICH., *January 25, 1931.*

DEAR PROFESSOR HENRY: Hydraulic engineers thus far have been in a quandary. In a continental climate, as that of the United States, the water problem is, for great parts of the country, that of a deficiency. The economics of projects costing millions depend on an accurate estimate of the quantity of water which is available, or will be, in the future. The theory that future averages will be equal to past averages has led to financial failures in a number of cases. I have personally been involved in two of them during the past 20 years.

Hence we have been forced to cast about for other solutions, and while we believe we are on the right path, this is strictly an engineering belief. Engineers are in every branch striding far ahead of scientific certainties and proceed on "opinion," "judgment," "hunch," and so forth. Hydrodynamics is still in a very elementary stage as far as the possibility of computing flow of water is concerned, but still engineers build water turbines of 93 per cent efficiency, largely empirically.

Hence the report should be regarded from that standpoint. It is a technical expedient. I fully disclaim its scientific value. And it should be regarded as wholly in the field of hydraulic engineering. I really feel very little informed about meteorology.

Respectfully yours, A. STREIFF.

A METHOD OF DETERMINING THE ALTITUDE IN THE ATMOSPHERE ABOVE SEA LEVEL WHERE THE FREEZING POINT OF WATER OCCURS

By J. F. BRENNAN, Government Meteorologist
[Kingston, Jamaica]

There are many devices already in use for registering the temperature, relative humidity, pressure, etc., aloft, such as self-registering meteorographs attached to sounding balloons, which are costly, and some delay is occasioned when recovering these instruments.

It is well known that the property of water is to expand at the instant of freezing by about 10 per cent.

Now, if a short length of copper tubing of about 0.10 inch bore with walls about 0.02 inch thick, be bent in the shape of a horseshoe, as per sketch (fig. 1), then filled with water (preferably distilled), the ends compressed in a vice and soldered, made quite free of air. At the moment of the water freezing the arms A—A will separate over half an inch. Therefore if a ring of metal wire be strung around A—A it will become disengaged at the moment of separation of the arms. A short length of thread F (about 12 inches), is secured to a paper pendant, D, and then attached to the ring B. The upper part of the horseshoe, at C, takes a length of thread, F_2, about 10 feet, to the closed mouth of the inflated pilot balloon E. The curved portion of the copper horseshoe tube, at C, should be flattened (somewhat similar to that of a Bourdon steam gauge), so that the major diameter of the elliptic section will be double that of the transverse diameter. This flattening will, of course, aid to insure suitable separation of the arms A—A.

When all be in readiness the thread F_2 above the horseshoe should be held by the fingers, and not at F_1, for the reason that the free-lift of the balloon is apt to permit the ring B to escape by strain.

At the moment the pilot balloon attains the altitude of freezing of water the pendant D falls away, and the altitude at this moment noted.

Mr. Brennan in his letter to the Weather Bureau adds the following:

> Inclosed you will find one of the actual horseshoe copper tubes which was experimented upon, when placed in a freezing mixture of ice and salt. I have exposed quite a number, and the separation of the arms A—A upon the moment of freezing of the water had a maximum expanded space of 1½ inches, when it fractured at the point C on the flattened curve of the tube.
>
> The total weight of the copper tube and pendant used did not exceed 20 grams, but no doubt the device can be contrived to be much lighter if necessary.
>
> It is just possible that much lower temperatures than 32° F. at greater altitudes may be determined by filling the tube with distilled water mixed with a small amount of glycerine, or other suitable soluble substance, whose freezing point is predetermined in the laboratory. Two or three pendants, mixed with different solutions, may be attached to a balloon, so that the temperature gradient up to great altitudes may be secured during a single pilot-balloon ascent.—*Editor.*

NOTE.—Since the receipt of Mr. Brennan's original communication he has submitted the following:

> On January 30 I tried my device with two separate balloon ascents. The first failed on account of entering cloud at low altitude, and the second ascent on February 2 attained an altitude a little beyond 7,640 meters, but the pendant did not detach, whereas the freezing of water would have been met at a much lower altitude, in the vicinity of about 5 kilometers according to a graph on page 301, of this REVIEW 55:301, Figure 5.

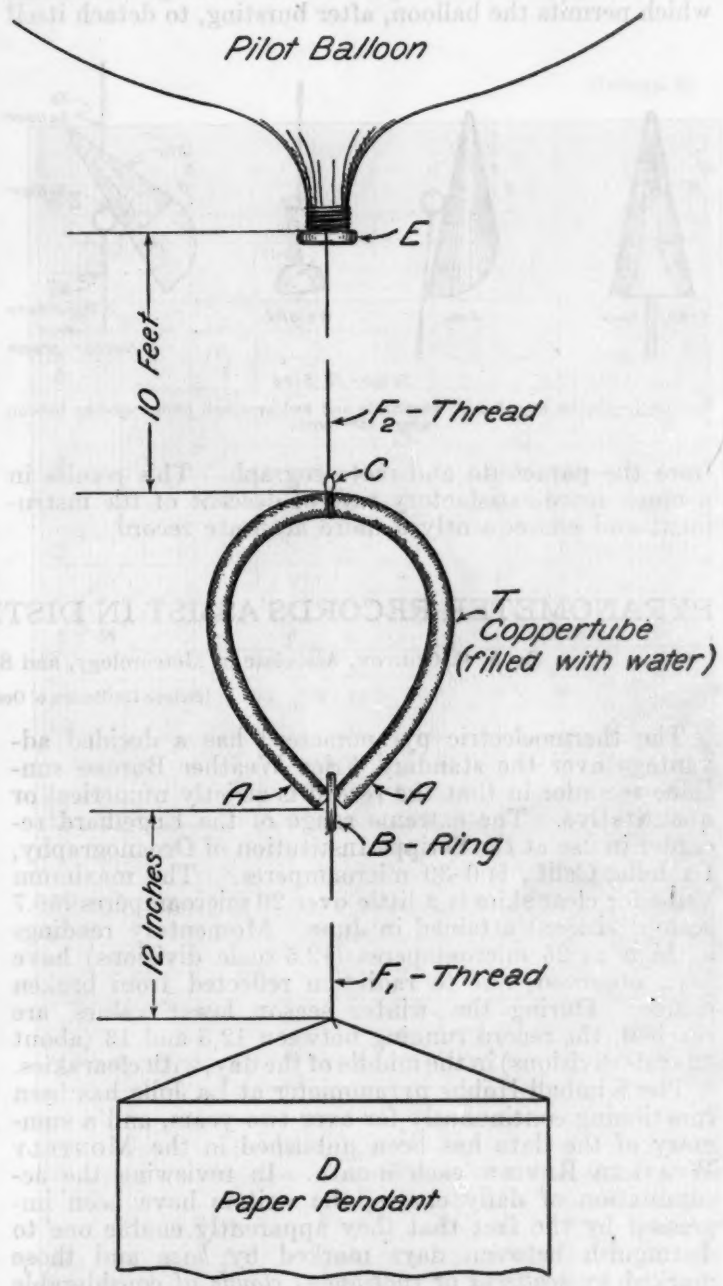

FIGURE 1

In a further letter dated March 30, 1931, Mr. Brennan gives an account of placing his device in a freezing mixture in which the arms of the tube separated at 23.5° F. A second test gave a similar result. He further estimates that the pendant should release in the latitude of Jamaica at about 6 kilometers altitude.

SOUNDING-BALLOON RELEASING DEVICE

By L. T. SAMUELS

A very satisfactory device has been designed by Mr. Berlin Pugh, of the Royal Center aerological station, which permits the balloon, after bursting, to detach itself from the parachute and meteorograph. This results in a much more satisfactory rate of descent of the instrument and consequently a more accurate record.

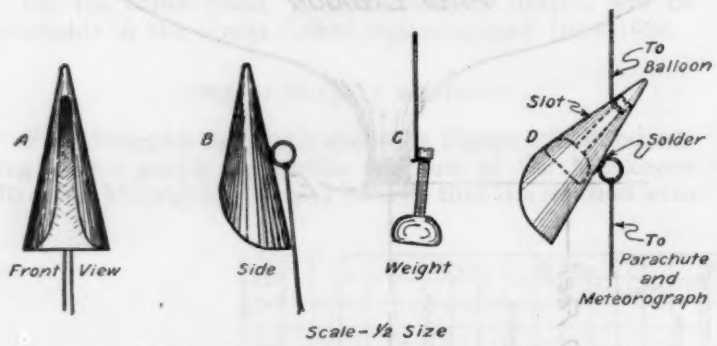

FIGURE 1.—Device for releasing parachute and meteorograph from sounding balloon after latter bursts

This device is shown in Figure 1 and consists of two parts, one, an aluminum slotted cone and the other, a brass weight. In Figure 1 *d* is shown how the two parts are used in an observation. One end of a cord is tied to the brass weight and the other end to the balloon. The brass weight is held inside the cone by the upward pull of the balloon. When the latter bursts, the brass weight slips out of the cone and the parachute is then free to operate during the descent of the instrument. A small wad of paper is put into the pointed end of the cone to prevent the brass knob from sticking.

The parachute used by the Weather Bureau is simply a square yard of bright red China silk. Cords are fastened to each corner and to the center. The other end of the cord attached to the center of the parachute is fastened to the aluminum cone. A light wire hoop about 1 foot in diameter is tied to the four cords attached to the corners of the parachute and prevents them from tangling and assures the opening of the parachute.

These devices were used with excellent results during a sounding balloon series at Royal Center, Ind., during February, the international month for 1931.

PYRANOMETER RECORDS ASSIST IN DISTINGUISHING BETWEEN HAZE AND CLOUDS

By A. F. GORTON, Associate in Meteorology, and S. W. CHAMBERS, Associate in Physical Oceanography

[Scripps Institution of Oceanography, La Jolla, Calif.]

The thermoelectric pyranometer[1] has a decided advantage over the standard Friez Weather Bureau sunshine recorder in that the record is strictly numerical or quantitative. The extreme range of the Engelhard recorder in use at the Scripps Institution of Oceanography, La Jolla, Calif., is 0–30 microamperes.[2] The maximum value for clear skies is a little over 20 microamperes (66.7 scale divisions) attained in June. Momentary readings as high as 25 microamperes (82.5 scale divisions) have been observed, due to radiation reflected from broken clouds. During the winter season lower values are reached, the record running between 12.5 and 13 (about 42 scale divisions) in the middle of the day, with clear skies.

The Kimball-Hobbs pyranometer at La Jolla has been functioning continuously for over two years, and a summary of the data has been published in the MONTHLY WEATHER REVIEW each month. In reviewing the accumulation of daily charts, the writers have been impressed by the fact that they apparently enable one to distinguish between days marked by *haze* and those marked by *scattered* or *continuous clouds* of considerable density, including "high fog."

Accompanying this note are sample charts which illustrate quite clearly the point in question; i. e., that the instrument easily distinguishes between what we may term "vapor," filmy cloud such as light cirrus, and clouds of material density. To be specific, that portion of the record of an apparently flawless day which is marked by a solid but jiggly line is due to what we have here called "vapor." This vapor or haze is often absolutely invisible to the eye. On the other hand, when scattered clouds of more or less density are present, the record jumps very erratically, changing as much as 4 to 8 microamperes in a few minutes' time. Furthermore, on days marked by dense cloud and rain, it is noticed that the line traced by the instrument is rather continuous but lies close to zero—in fact, the intensity may be six, four, or even less, scale divisions,[3] as is well shown by the records for May 5 and 16, reproduced in Figures 1–A and 2, respectively.

As previously stated, the instrument responds to scattered clouds by fluctuating between wide limits (figs. 1–B and 3), and on very bright, clear days makes a trace which is quite solid, i. e., *continuous*, but varies as much as 5 or 6 per cent during time intervals as short as 10 to 20 minutes. As illustrations of this point we cite the records for the afternoon of May 5 and 22, Figures 1–C and 4, respectively.

Finally, we have noticed another peculiarity of the instrument; that is, a tendency when scattered clouds are present for the record to exceed by as much as 2 to 3 microamperes the very maximum for a normal clear day. (See records for May 5 and 28, reproduced in Figures 1–B and 3, respectively.)

It is recognized, of course, that various types of haze, fog, and cloud exist, and here on the Pacific coast it is often difficult to distinguish precisely between them. We have observed, however, that variations of as much as 5 microamperes may be caused by what most people term "high

[1] Kimball, Herbert H. and Hobbs, Hermann E.: A new form of thermoelectric recording pyrheliometer. Monthly Weather Review, May, 1923, vol. 51, p. 239.

[2] It would be preferable to state the output of the thermocouple system in millivolts, but the latter may be calculated from the relation: E. M. F. in microvolts=412×current in microamperes. To reduce microamperes to gram-calories per minute per square centimeter, multiply by 0.055. Thus, 30 microamperes equals 1.65 gr.-cal./min./cm², and 20 microamperes equals 1.10 gr.-cal./min./cm². Also, scale readings on the record sheet may be reduced to gr.-cal./min./cm² by multiplying by 0.0165. A recent test by the Scripps Institution shows that the register has not changed in the three years it has been in service.

[3] Kimball, Herbert H.: Records of Total Solar Radiation Intensity and Their Relation to Daylight Intensity. MONTHLY WEATHER REVIEW, October, 1924, vol. 52, p. 473, fig. 5.

(To face p. 76)

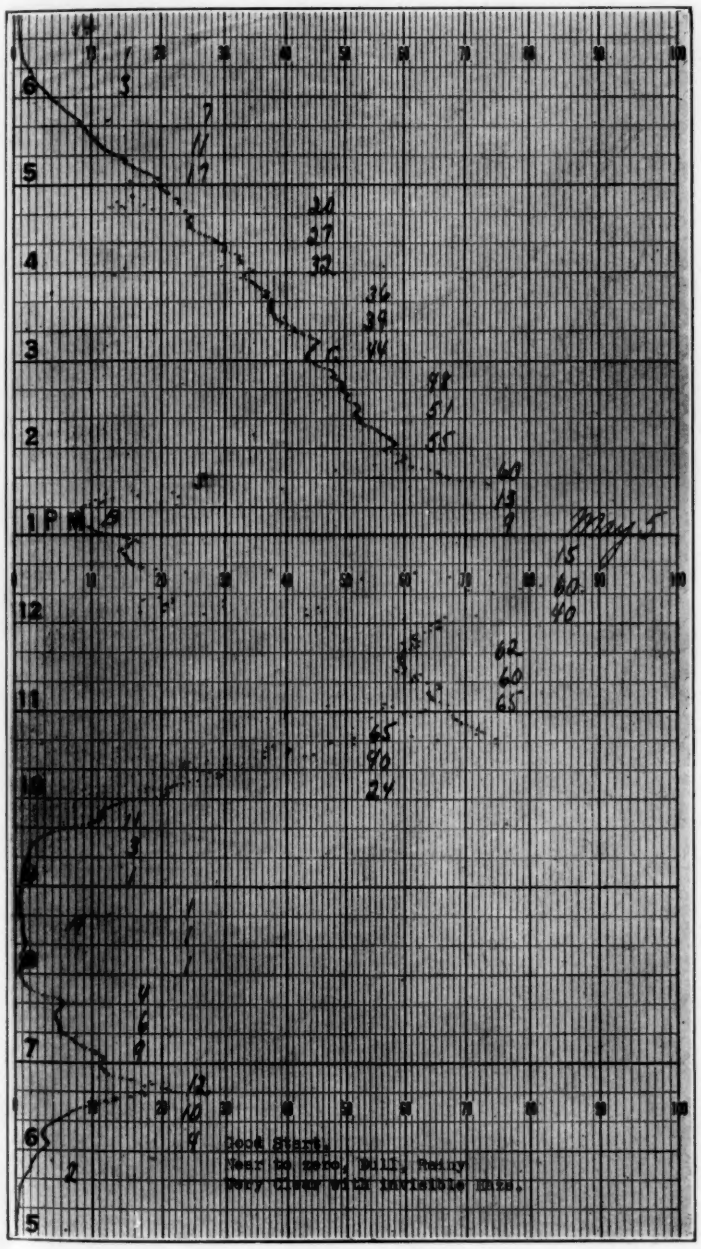

FIGURE 1.—Record for May 5, 1930. A, Dense cloud and rain; B, scattered clouds; C, invisible haze

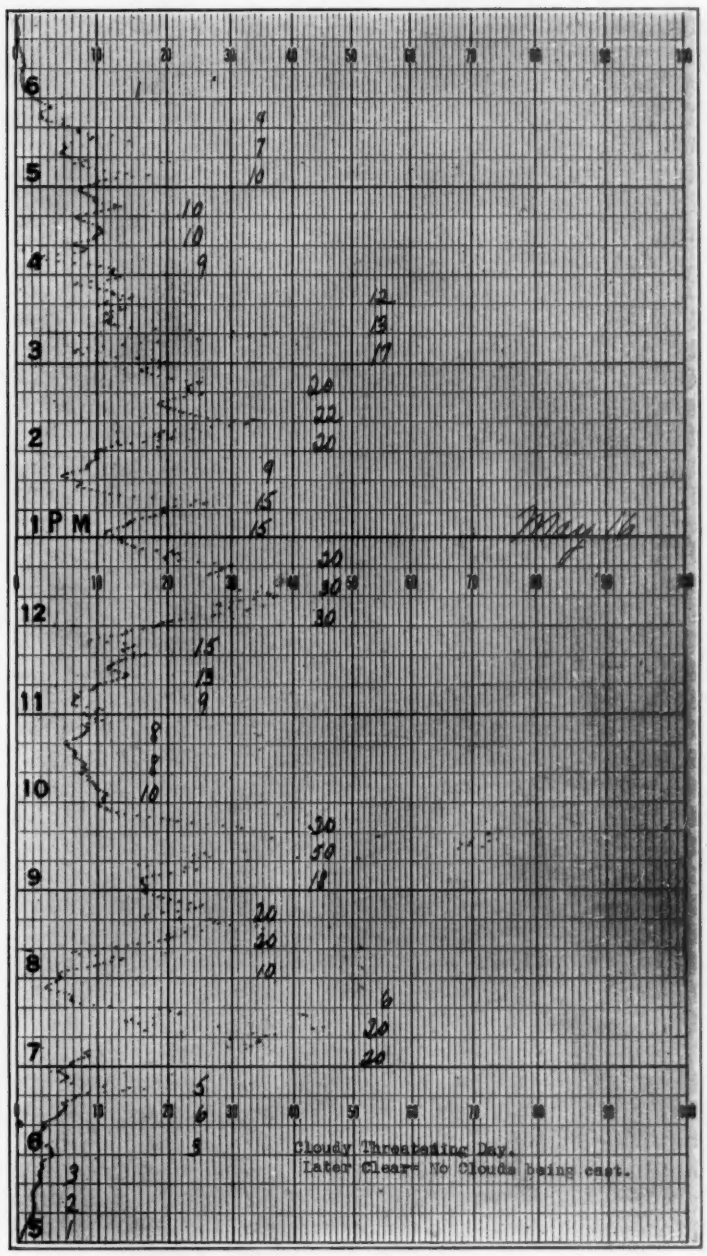

FIGURE 2.—Record for May 16, 1930. Cloudy day, with no shadows cast

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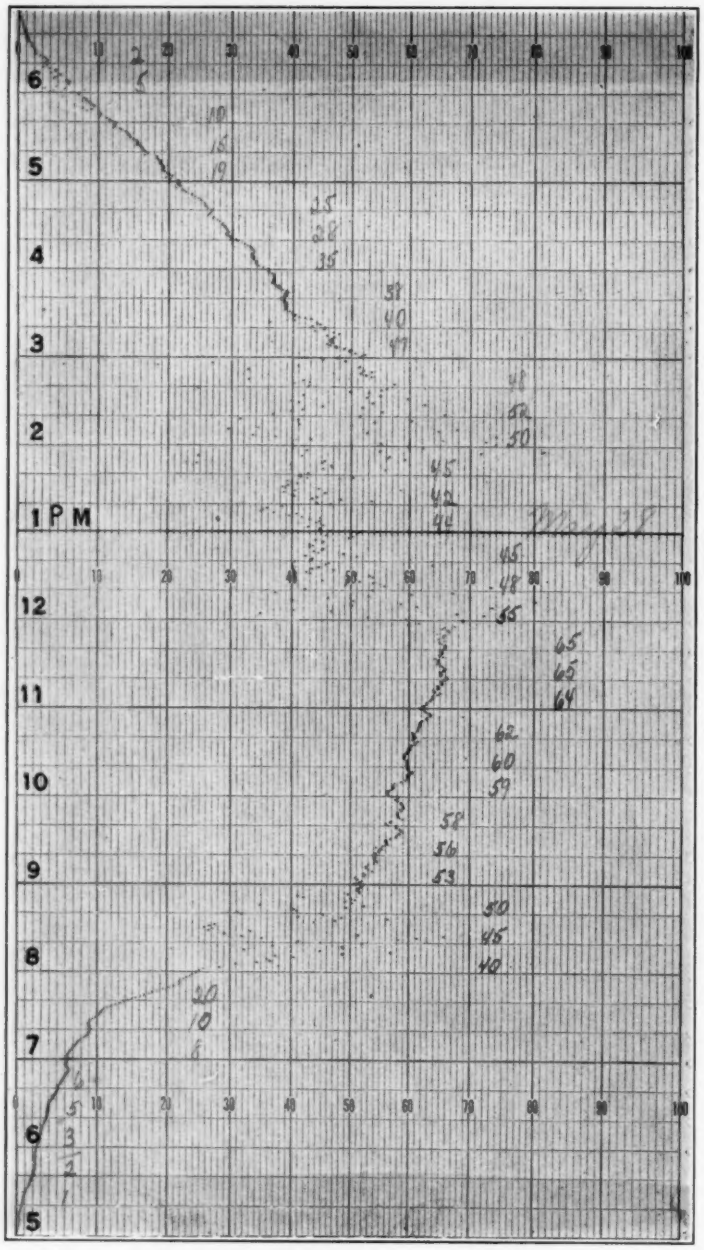

FIGURE 3.—Record for May 28, 1930. High fog

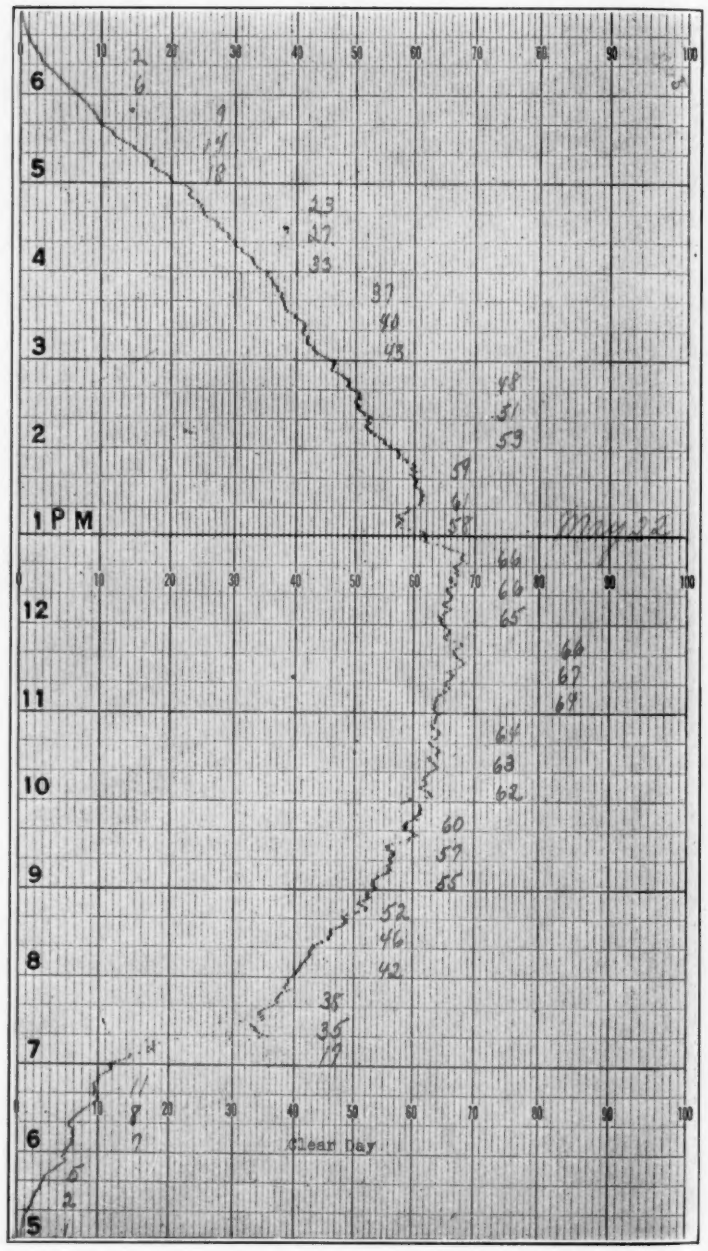

FIGURE 4.—Record for May 22, 1930. Invisible haze

(To face p. 76)

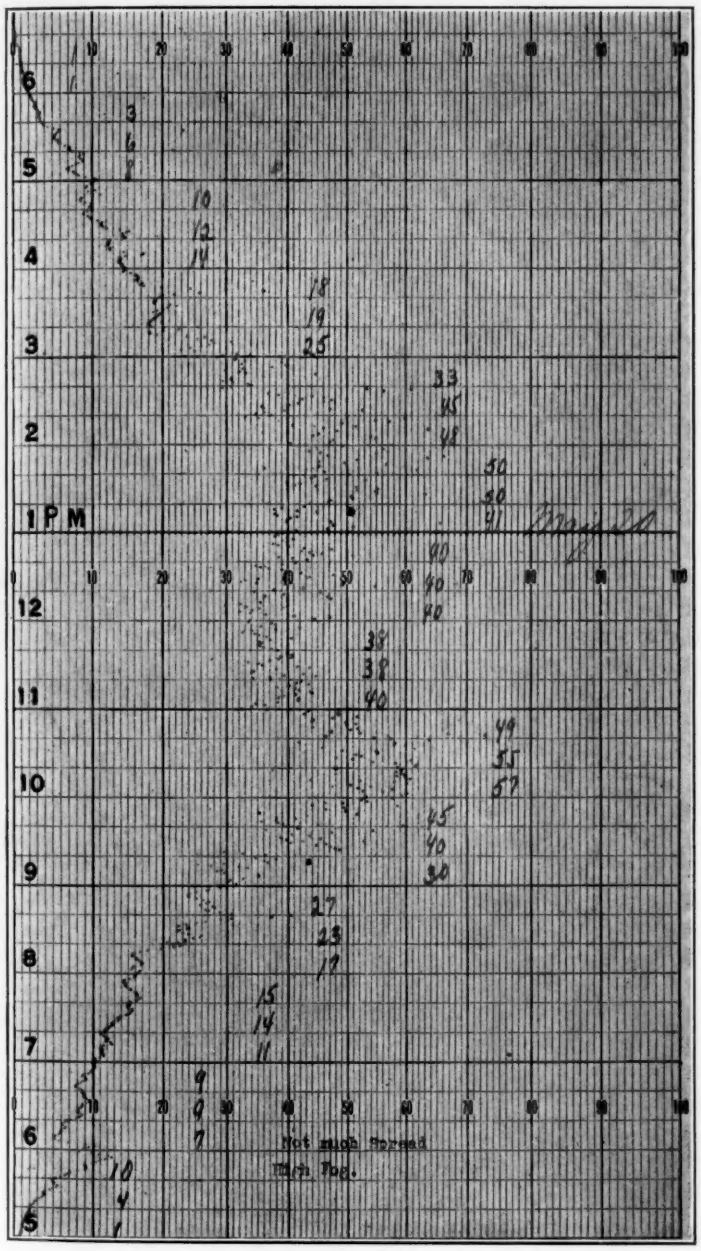

FIGURE 5.—Record for May 20, 1930. High fog

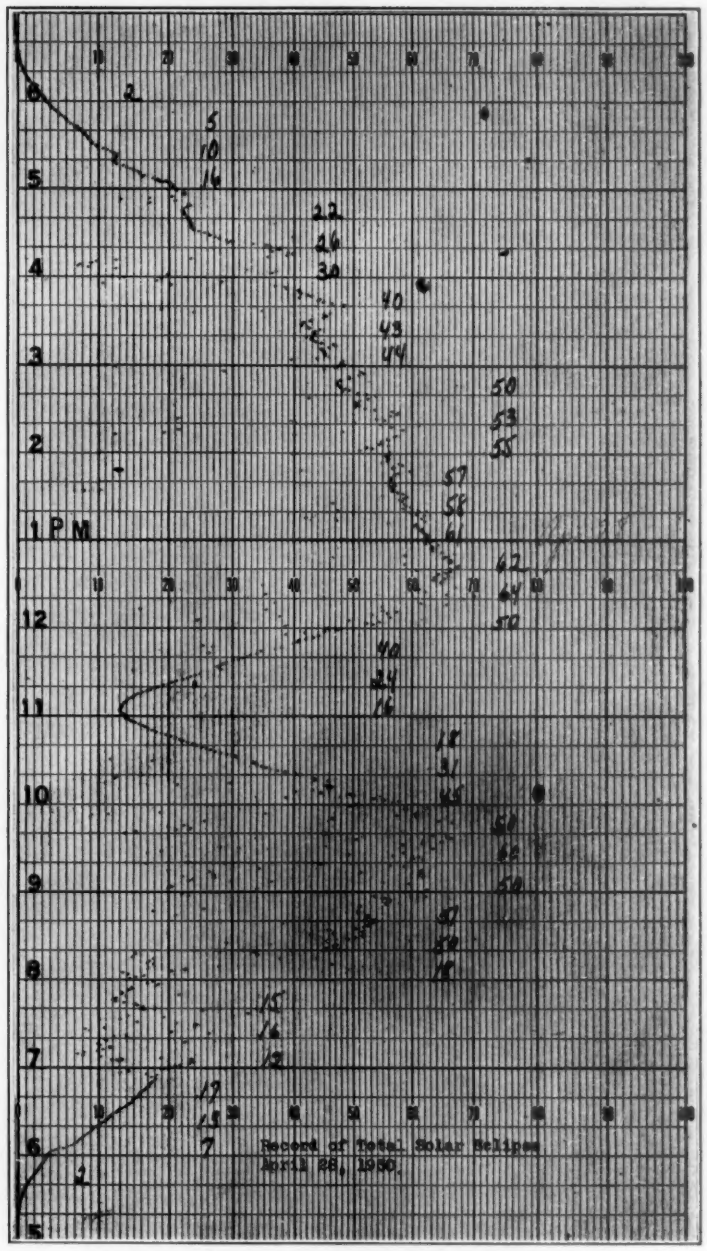

FIGURE 6.—Solar eclipse of April 28, 1930

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fog." This term should be applied to cloud banks of considerable continuity and density,[4] and not confused with cirrus (high altitude) clouds or with ordinary "low fog."

Possibly we may establish a safer criterion by determining whether a shadow is being cast. We have observed that in some cases the record varies over 5 microamperes, but the total intensity is not much reduced below the maximum for a clear day. In these cases it was noticed that shadows were cast. On the other hand, when the cloud density increases sufficiently a shadow is no longer cast and the record sinks to 6 microamperes or less. As an illustration of some of these points we may cite the record for the day of the total solar eclipse, April 28, 1930. (See fig. 7.) Here it will be noticed that the trace becomes quite continuous below 12 microamperes (40 on the chart) having the smoothness of a record for a clear day but forming a beautiful V-shaped indentation in the record.

Kimball,[3] in several articles dealing with the design, construction, and performance of the pyranometer, refers to irregularities in the traces of the instrument on apparently clear days but comes to no definite decision regarding the probable cause of the irregularities. On another occasion he states that they may be caused by smoke. At a location like La Jolla, this hypothesis is ruled out, since the atmosphere is always smoke-free except on rare occasions when there are forest fires.

[4] See Carpenter, Ford A.: The Climate and Weather of San Diego. 1913, pp. 5-7.

[3] Kimball, Herbert H.: Records of Total Solar Radiation Intensity and Their Relation to Daylight Intensity. MONTHLY WEATHER REVIEW, October, 1924, vol. 52, p. 473, fig. 5.

SOME CHARACTERISTICS OF CONTINUOUS RECORDS OF THE TOTAL SOLAR RADIATION (DIRECT+DIFFUSE) RECEIVED ON A HORIZONTAL SURFACE

By HERBERT H. KIMBALL

In the paper preceding this, Gorton and Chambers have pointed out some interesting relations between the character of solar radiation records and the condition of the sky. Ångström [1] has already noted some of these relations at Stockholm, and especially the increased intensity with the sun shining between broken clouds.

In an earlier paper entitled "On Continuous Radiation Records and Their Bearing upon Geophysical Problems." (Särtryck ur Förhandlingar 17: de skandinaviska naturforskaremötet i Götchorg, 1923) he discusses the cloud formation during the passage of a cold-wave front at Stockholm on August 4, 1922. The formation of a uniform cloud layer preceded the arrival of the cold air at the surface by an appreciable time interval, and breaks occur in this cloud layer at uniform intervals of two hours. This is explained as follows:

> The upper boundary of the cold wave is in general subjected to a pronounced wave formation. Sometimes waves of higher orders are well developed. As a rule the uniform cloud layer appears at the wave tops, the breaches in the cloud layer at the valleys, but exceptions therefrom sometimes occur. In the special case referred to above the breaches in the cloud layer have occurred almost exactly at the lowest points of the waves.

Apparently, atmospheric waves sometimes occur without forming visible clouds. For example, in the MONTHLY WEATHER REVIEW for September, 1915, volume 43, page 441, in Figure 1 are plotted logarithms of solar radiation intensity against air mass, measured on unusually clear days. With a sky of uniform clearness throughout, the plotted values should fall on a line only slightly concave upwards. Actually, however, the values fall on a wavy line, and especially those for Washington, during the afternoon of February 28, 1915, and for Mount Weather, Va., during the morning of September 28, 1914.

Attention has also been called to the effect of smoke on the solar radiation intensity. See, for example, MONTHLY WEATHER REVIEW, volume 52, page 478, Figure 5, October, 1924, and volume 53, page 147, Figure 1, April, 1925. The first of these reproduces records of intensity of the total solar radiation received on a horizontal surface at the university station, Chicago, Ill., and its depletion by smoke on both a cloudless and a cloudy day. The second shows the depletion of direct solar radiation intensity at normal incidence at the American University, District of Columbia, by a smoke cloud that was brought over the university from the city by an east wind. Clouds of less density frequently cause depressions in the records obtained in the vicinity of any city.

It is apparent that much valuable information about sky conditions may be obtained from continuous records of the intensity of solar radiation as received on either a horizontal surface or on a surface normal to the incident rays.

[1] Ångström, Anders. Recording solar radiation. Medd. Från Statens Meteorologisk-Hydrografiska Anstalt, Band 4, No. 3, 1928.

COMPARISON OF ROOF AND GROUND EXPOSURE OF THERMOMETERS

By BERNARD R. LASKOWSKI

[Weather Bureau, Topeka, Kans.]

It is generally conceded that the average temperature readings obtained from properly exposed thermometers in the Plains States, where the ground surface is level or slightly rolling, agree quite closely within a radius of from 15 to 25 miles. What, however, is the relation between official temperatures taken in downtown sections of middle-western cities and their suburbs? In other words, do official temperatures taken on high buildings of cities reflect conditions under which people live in the residence sections? It must be remembered that in a great percentage of the larger cities the usual practice is to locate the thermometers on roofs of high buildings, while in the suburbs, the thermometers are more likely to be exposed over a ground surface. In order to investigate this question a 6-year record of daily maximum and minimum temperature readings was obtained in Topeka, Kans.

The thermometers used in this study were of standard pattern, compared for accuracy, and exposed in standard shelters having louvered sides and double-decked roofs. These favor the free circulation of the passing air, but do not absorb any added heat due to radiation or reflection from near-by objects or from the direct rays of the sun. One set, that of the Weather Bureau office, was

located 10 feet above the flat roof of a 6-story building, making an actual elevation of thermometers 92 feet above street level, in the center of the business district, and the other 5½ feet above the ground at a point a mile and a half away in the residential section. The size of the ground shelter is 21 by 32 inches; it has not a broad platform underneath it. The ground surface at both places is approximately the same elevation above sea level.

During the period of comparative readings some of the lowest readings ever recorded in the vicinity, as well as the highest on record in 44 years, occurred. This should eliminate the objection that just average conditions had prevailed during the experiment and extreme conditions might have altered the results obtained.

In most instances the individual monthly averages obtained from the ground surface readings were higher. Occasionally, though, during no definite seasons, the opposite was true. The wind movement and presence of snow and ice on the ground seem to have been the most apparent factors in making the differences so far as the study indicates. Taking the monthly averages for the six years into discussion, it is found that these averages compensate the individual monthly inconsistencies and the ground exposed readings exceed the roof readings each month, and for the entire period average by 0.6°. This fact in itself eliminates any need for correction for altitude, as the ground instruments are less than 100 feet below those on the roof. In case there was a noticeable altitude effect, it would tend to lessen the differences instead of increasing them.

The monthly mean maximum and minimum temperatures and extremes add more to the study than do the average readings. The ground-exposed maximum thermometer averaged 1.9° higher than the roof thermometer, while the minimum readings averaged 0.6° less. This may be accounted for by stating that the radiation effect at the ground should be greater than on the roof, where air passage is less hampered. This conclusion is indicated by the tables giving the monthly extremes and the extremes for the entire period. Whereas the monthly averages do much towards eliminating the observed discrepancies, the daily extremes exhibit examples of the various individual factors that tend to separate or draw together the readings.

For an example of wind effect, let us refer to several dates selected at random. On April 24, 1926, the wind, as recorded at the Topeka Weather Bureau office, averaged 19.9 miles per hour for the day, which is above the daily average wind movement. The high wind kept the air mass in continual turmoil, the result being a minimum temperature at the ground of 45° and on the roof 46°.

On June 9, 1927, the daily wind averaged 16.7 miles per hour and the minimum readings at both places were the same, 66°. On September 11, 1928, the wind averaged 13.0 miles per hour and the minimum on the ground was 64° while on the roof it was 63°. On December 2, 1929, the wind averaged 10.3 miles per hour, and again both thermometers registered the same, 10°.

Radiation effect is greater if the wind movement is light, permitting the air mass to become stagnant. The dates selected to illustrate this part of the wind factor are as follows: On April 26, 1926, with an average wind movement of 5.6 miles per hour, the minimum on the ground read 37° and the roof thermometer 42° On July 2, 1927, the wind averaged 5.5 miles per hour and the ground minimum was 57° while the roof minimum was 64°. On September 15, 1928, with an average wind movement of 3.3 miles per hour, the ground thermometer registered 54° and the roof thermometer 61°. On November 1, 1928, the wind averaged 4.9 miles per hour and the minimum on the ground was 29° while on the roof it was 34°. All the days considered in these cases were either clear or mostly so. It will be observed that the days selected represent each quarter of the year which indicates that this factor is not limited to any particular season.

For cases to demonstrate what effect a snow blanket has on the ground temperature we refer to the period of January 12 to 16, 1927. Snow several inches in depth occurred on the 12th and 13th, leaving 4 inches on the ground at the close of the 13th. The next morning with a clear sky and wind averaging 10.2 miles per hour, the ground thermometer registered 5° while the roof thermometer registered 8°. Practically the same sky and wind conditions prevailed through the 16th. On the 15th the ground thermometer read 14° below zero and the roof thermometer 9° below zero. On the 16th the ground minimum was 16° and roof reading 23°. The period of January 22 to 25, 1930, also illustrates this point. Previous to the 22d, snow had fallen and the ground was covered to a depth of 9.0 inches. The sky was clear from the night of the 21st to the morning of the 25th. The average wind movement the 21st to 22d was about 5 miles an hour. The ground thermometer that morning read 19° below zero and the one on the roof read 13° below zero., which by the way, is the lowest recorded at the Weather Bureau in 11 years. The wind movement from the 23d to the 25th averaged between 9 and 10 miles per hour. On the morning of the 23d, the ground reading was 7° below zero while the roof reading was 1° above zero. On the 24th the low point at the ground was 9° compared to 12° on the roof. The morning of the 25th the ground thermometer indicated 3° and the one on the roof 11°.

The daily maximum readings did not show as great differences as the minimums, but this can be accounted for by the fact that the maximum generally occurs in the latter part of the afternoon when the wind movement is at its highest, resulting in the air mass at the ground at that time being about as active as on the roof. For this reason the maximum readings on the roof and ground agreed uniformily within one or two degrees, and any number of times were exactly the same. A case in this connection was August 3, 1930, when the Weather

Bureau thermometer registered 110°, which was the highest reading ever recorded in 44 years. The ground thermometer corresponded exactly. The sky was mostly clear and the wind averaged 11.9 miles per hour.

The slightly higher day readings and lower night readings signified that the daily range must be proportionately greater at the ground. This varied from time to time. For the entire period the monthly mean daily ranges differed by 2.4°. The daily range varied from day to day, sometimes being close together and then again at wide variance. The greatest differences occurred during quiet spells when the radiation effect was greatest.

Actual practice in the United States Weather Bureau is to employ ground exposure at some 4,500 cooperative stations and at as many first-order stations as possible. Roof exposures are accepted only through necessity, never from choice.

The results of the comparative readings are summarized on a monthly basis in the table below.

TABLE 1.—*Summary of comparative readings, monthly means, and extremes*

Stations	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Monthly means, ground	26.9	37.6	46.3	57.1	64.9	73.0	79.6	77.6	70.5	57.8	43.2	31.8	55.5
Monthly means, roof	26.6	37.0	45.0	56.0	64.4	72.2	79.0	77.3	69.8	57.9	42.6	30.8	54.9
Monthly means, maximum ground	36.9	48.7	58.9	68.8	76.5	83.9	91.2	89.2	81.8	69.4	54.0	42.0	66.8
Monthly means, maximum roof	35.6	46.7	56.1	66.1	74.8	82.0	89.3	88.0	80.0	68.4	52.3	39.9	64.9
Monthly means, minimum ground	16.9	26.5	33.7	45.5	53.3	62.1	68.0	65.7	59.2	46.1	32.3	21.6	44.2
Monthly means, minimum roof	17.6	27.4	34.0	45.9	53.9	62.4	68.7	66.6	59.6	47.4	32.9	21.7	44.8
Absolute maximum, ground	66	83	89	93	95	99	105	110	102	93	83	68	110
Absolute maximum, roof	68	83	88	93	96	100	104	110	101	93	84	68	110
Absolute minimum, ground	−19	−11	0	14	34	46	51	49	35	16	5	−9	−19
Absolute minimum, roof	−13	−7	4	17	35	49	52	52	38	16	10	−9	−13

FURTHER NOTES ON THE EFFECT OF WEATHER ON APPLE YIELDS

By W. A. MATTICE

[Weather Bureau, Washington, D. C.]

The effect of temperatures on apple yields was studied during 1927 by the author and the results published in the Monthly Weather Review.[1] The effect of precipitation, however, was not considered at that time as the purpose of the study was to substantiate the theory that spring temperatures were largely a determining factor in apple production. The precipitation by months was studied rather casually in a preliminary survey, but no definite relationship was established. However, a bulletin of the New York Agricultural Experiment Station by R. C. Collison and J. D. Harlan[2] was forwarded by the senior author for information as regards its conclusions. This publication contains the results of a rather exhaustive survey of an orchard of 50 Rome Beauty apple trees in New York. The conclusions drawn are that temperature departures from normal are not an important factor influencing yield, but that precipitation departures from normal are very important, especially those for the period from July 16 to September 1. It is also shown that the most critical period of these six weeks is that between July 31 and August 15. These conclusions, if they could be correctly applied to the entire State, would depreciate the spring temperature theory. In order to check these conclusions with State yields it was decided to collect rainfall data from the temperature stations and find such relationships as might exist.

The daily precipitation for three months, June to August, inclusive, was obtained and weekly amounts computed. Thus, the weekly periods covered the time from June 1 to August 30 and should show the critical period by the magnitude of the correlation coefficients.

The individual correlation coefficients for these 13 weeks are given below:

Week ending—	Correlation coefficient	Week ending—	Correlation coefficient
June 7	−0.14	July 26	0.07
June 14	.23	Aug. 2	−.06
June 21	.21	Aug. 9	−.05
June 28	−.18	Aug. 16	−.22
July 5	.36	Aug. 23	.20
July 12	−.29	Aug. 30	.14
July 19	.06		

The magnitude of the coefficients is very small, the largest being only 0.36, which is hardly large enough to consider. There is some significance, however, in the largest coefficients occurring in pairs, as it would appear from this 2-week periods are of more importance than single weeks. The coefficients of these 2-week periods with yield, by multiple correlation methods, were: June 7–21, 0.26; June 29–July 12, 0.59; August 9–23, 0.29. The increase of the coefficient for the weeks June 29–July 12, from 0.36 to 0.59, is rather striking. This is due to the fact that, while the two weeks have a positive and negative relationship with yields, the correlation between them is positive; thus the relation of both with yield is very much better in combination than separate.

The three 2-week periods were combined in a multiple correlation, giving a coefficient of 0.64, or only 5 points better than the coefficient of the weeks June 29–July 12. These six variables then were put into an equation in order to compute yields from them. The equation follows:

$$\overline{X}=1.14\,A-0.31\,B+3.16\,C-5.30\,D+0.95\,E+2.34\,F+8.22$$

The letters A, B, C, etc., refer to the single weeks, June 14, June 21, July 5, etc.

The computed yields from this equation gave a reduction of the standard deviation of 23 per cent. The reduc-

[1] Mattice, W. A. (1927): The Relation of Spring Temperatures to Apple Yields. MONTHLY WEATHER REVIEW, 55, 10: 456–459.

[2] Collison, R. C., and Harlan, J. D. (1927): Annual Variation in Apple Yields—A Possible Cause. Technical Bulletin No. 126, New York Agricultural Experiment Station, Geneva, April, 1927.

tion is rather small, but is valuable for forecasting purposes, as it enables one to come closer to actual yield than is possible using the average yield.

The use of these computed yields as a base for combination with the yields computed from the temperature data is following the method outlined by J. B. Kincer.[3] The yields computed from the rainfall data are called Yr and those from temperature Yt. Thus, the correlation coefficient, $rYtYrx=0.87$. This is an increase of 6 points over that obtained only from temperatures and gives a reduction of the standard deviation of 51 per cent, an increase of 10 per cent over that from temperatures alone.

It is not well to stop here, however, as some other combination of weeks might raise the coefficient. A small increase at these high values is very important, so it is worth while to try other combinations.

Thus, dropping the first week used, June 14, and combining the remaining weeks, gives a coefficient of 0.63, one point less than for the whole six weeks. It would appear that these weeks would not give such a high coefficient as the entire six, but the intercorrelation coefficient is only 0.39, against 0.46 for the whole period. The multiple coefficient is 0.88 against 0.87, or an increase of one point, a valuable increase, as there is a 2 per cent further reduction in standard deviation, bringing it to 53 per cent. The equation for computing yields from these latter variables was:

$$\overline{X}=0.58\ Yr+0.80\ Yt-3.93$$

Figure 1, shows the computed and actual yields for 1901–1925. The agreement is remarkably close, considering the range of the data, although a few years are still somewhat at variance with the actual yields.

[3] Kincer, J. B., and Mattice, W. A. (1928): Statistical Correlations of Weather Influence on Crop Yields. MONTHLY WEATHER REVIEW, 56, 2.

The standard deviation of computed from actual yields is 1.92, compared with the standard deviation of yield, 4.05; the reduction is 53 per cent, as before stated.

The period of two weeks ending with July 12 was also correlated with temperature and yield and produced a coefficient of 0.85, or only three points less than with the five periods and two less than with all six weeks. This, in itself indicates that the period from June 29–July 12 is a critical one for precipitation, although the other periods are of some slight importance.

Some other combinations were tried in order to exhaust all possibilities, but there was none that gave as satisfactory a result as that for five weeks.

The conclusions that can be drawn from the above statements are that temperatures are of major importance in the yield of apples, on a State basis, and that precipitation is only of secondary importance. These conclusions are possible only to State yields and can not be applied to single orchards, as demonstrated in the conclusions obtained by R. C. Collison.

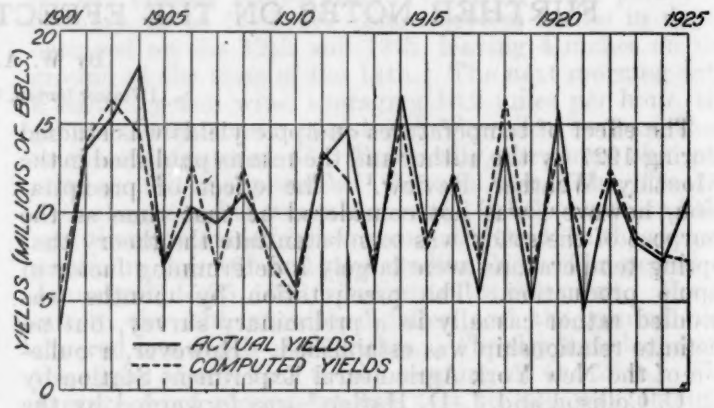

FIGURE. 1—Actual and computed yields of apples, New York State

EFFECT OF OZONE ON THE TEMPERATURE OF THE UPPER AIR

By EDWARD H. GOWAN

Two papers have been recently published by this author.[1]

The following abstracts are reprinted from Science Abstracts 32; 430 (1929) and 34: 58 (1931).

The illustrations are from the original papers.

The paper deals with the radiative equilibrium of the upper part of the atmosphere, taking into account the effects, with selective absorption, of water vapor and ozone. For material the author used (1) Abbot's curve for the distribution of energy in the solar spectrum from 0.4μ to 1.2μ and a black-body curve for 6,200° K. for 1.2μ to 6μ; (2) average radiation as for a black body at 260° K. from the earth and a moisture-laden atmosphere below 11 kilometers; (3) the amount of O_3 as constant and equal to a thickness of 3 millimeters at N. T. P. with a center of gravity at 30 to 40 kilometers; (4) a smooth average curve for absorption of O_3; (5) Fowle's figures for the absorption of H_2O vapor; and (6) saturation at 11 kilometers for 219° K. for H_2O vapour. Curves show the results obtained for temperature and height for (1) absorption and radiation due to H_2O vapor alone; (2) the observed amount of O_3 distributed as for O_2 down to 40 kilometers; and (3) an assumption of a change in distribution of O_3 to keep the temperature at 300° K. up to 150 kilometers. The effects on the temperature of (1) a different H_2O vapor distribution; (2) variation of absorption with temperature and pressure; and (3) a change in the center of gravity of the O_3 are discussed. The final temperature distribution arrived at agrees well with sound ranging and meteor observations.—*R. S. R.*

[1] Proc. Roy. Soc. London A 120:655 (1928) and A 128:531 (1930), the second paper being an extension of the first.

58. Effect of Ozone on the Temperature of the Upper Atmosphere, Part II, E. H. Gowan. Roy. Soc., Proc. 128, pp. 531–550, August 5, 1930. The method described in an earlier paper (see Abstract 430 (1929) is rendered more easy of solution by certain assumptions and allowance is made for diffusion of radiation from the earth. Preliminary estimates of the rate of cooling of the upper layers of the stratosphere and consideration of independent observational evidence of meteors lead to the belief that mixing of the constituents is general far above the tropopause. The radiation from the stratosphere must then be less and since the absorption of solar energy is the same, higher temperatures result. The maximum temperature attainable is investigated, this being governed by the rate of thermal decomposition of ozone and the rate at which ozone is formed in the atmosphere. The assumption of radiative equilibrium is reexamined in relation to convection being sufficient to insure mixing and the idea is retained. The effect of water vapor distributions for (*a*) no convection and gases in gravitational equilibrium, and (*b*) enough convection to give a constant composition is illustrated by calculations for varying conditions. The effects of different distributions and amounts of ozone and different zenithal angles of the sun are similarly treated. It is concluded that plausible distributions of ozone and water vapor provide the basis for a quantitative explanation of sound wave and meteor phenomena.—*R. S. R.*

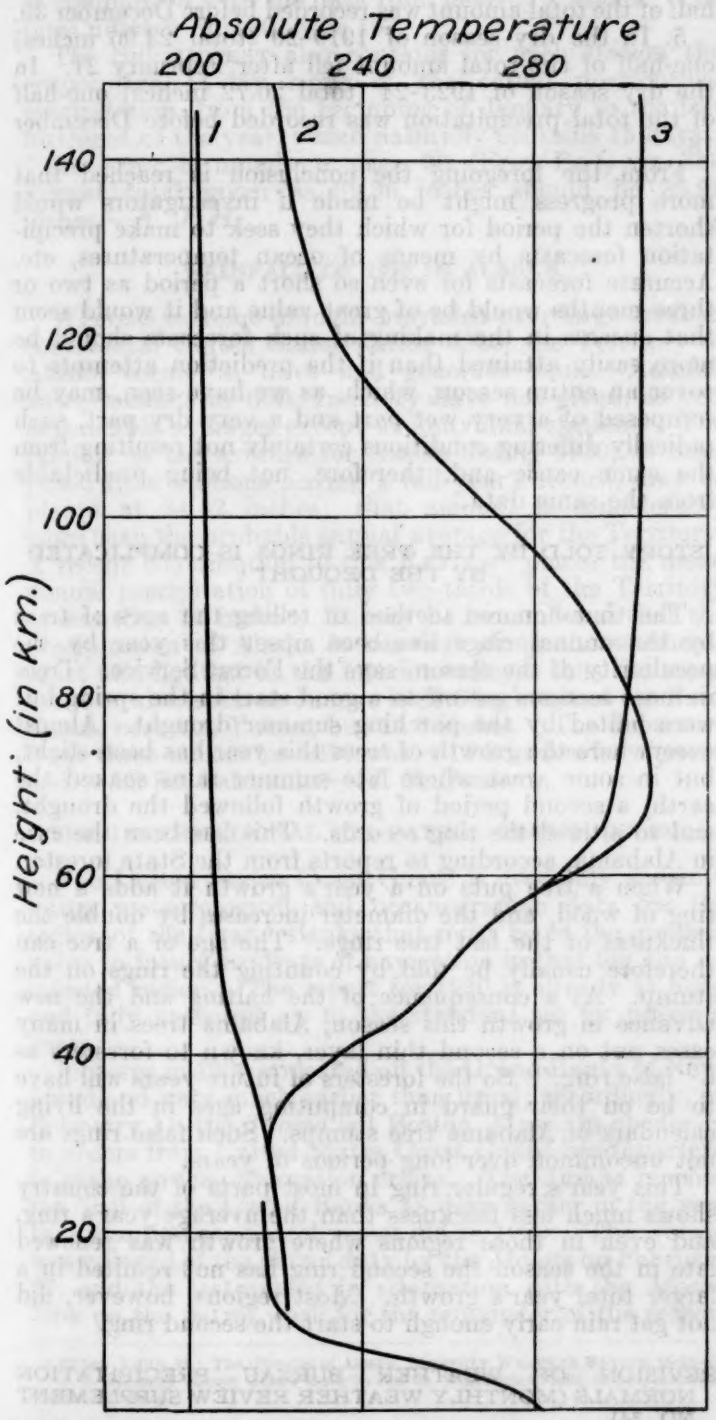

FIGURE 1.—Curve 1 shows an average of the balloon observations given by Sir Napier Shaw in Part II of his Manual of Meteorology. Curve 2 was obtained by considering the absorption and radiation of water vapor alone. The curve was intended for use as a basis of comparison. Curve 3 is the result when the observed amount of ozone is distributed so as to be proportional to the oxygen down to 40 kilometers. From 30 to 40 there is the same amount as in the layer from 50 to 60, and below that no appreciable amount is assumed

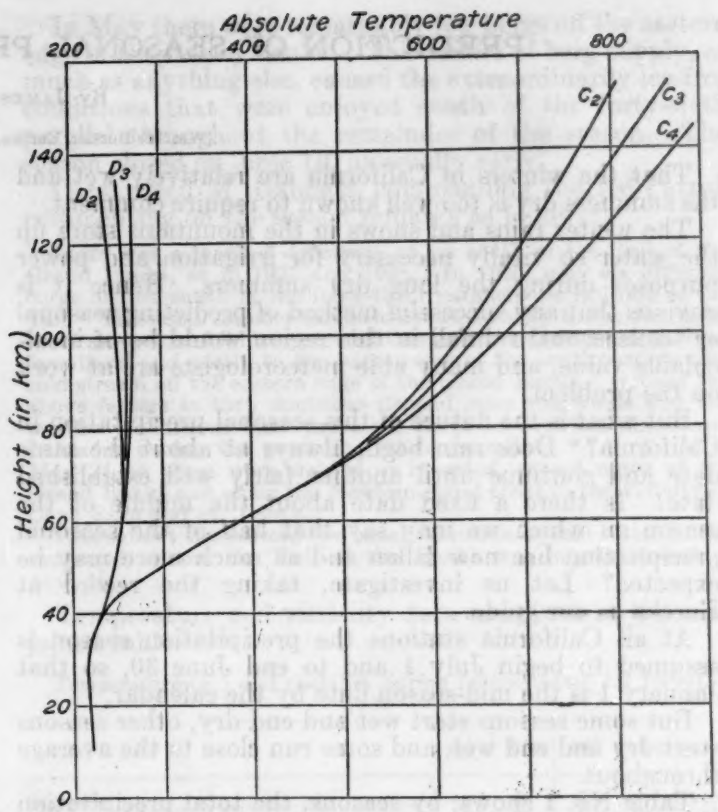

FIGURE 2.—Effect of variations in amount of ozone, distribution B. D-family: Water vapor distribution A. C-family: Water-vapor distribution B. Subscripts 2, 3, 4 represent total amount of ozone, millimeters

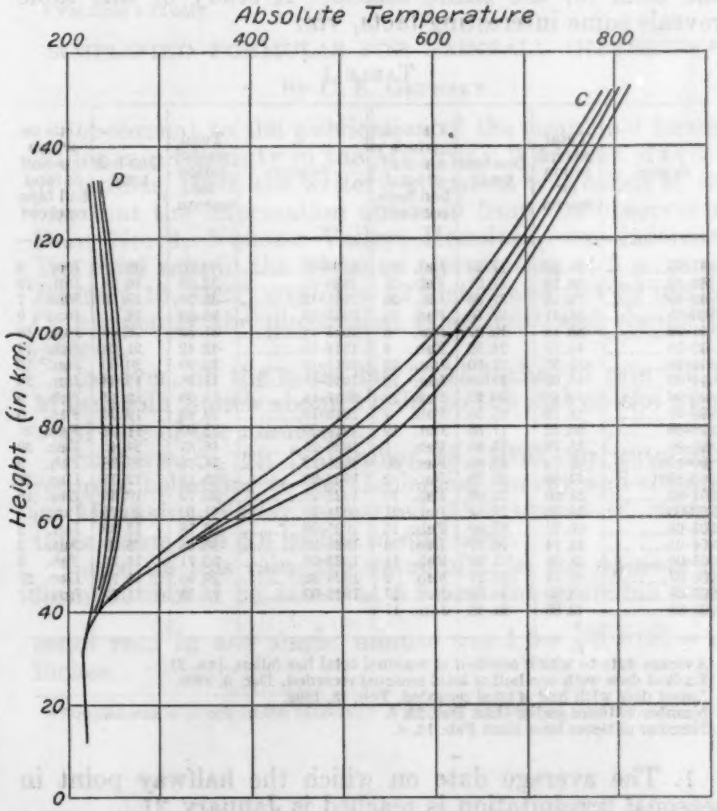

FIGURE 3.—Effect of zenith angle of the sun. Ozone distribution B for 2 millimeters total. D-family: water vapor distribution A. C-family: Water-vapor distribution B. From right to left the curves are for zenith angles of 0°, 28°, 48°, and 60°.

PREDICTION OF SEASONAL PRECIPITATION IN CALIFORNIA

By JAMES M. JONES

[Weather Bureau, Eureka, Calif., November 15, 1930]

That the winters in California are relatively wet and the summers dry is too well known to require comment.

The winter rains and snows in the mountains store up the water so vitally necessary for irrigation and power purposes during the long dry summers. Hence it is obvious that any successful method of predicting seasonal or semiseasonal rainfall in this region would be of incalculable value, and many able meteorologists are at work on the problem.

But what is the nature of this seasonal precipitation in California? Does rain begin always at about the same date and continue until another fairly well established date? Is there a fixed date about the middle of the season on which we may say that half of the seasonal precipitation has now fallen and as much more may be expected? Let us investigate, taking the record at Eureka as our guide.

At all California stations the precipitation season is assumed to begin July 1 and to end June 30, so that January 1 is the mid-season date by the calendar.

But some seasons start wet and end dry, other seasons start dry and end wet, and some run close to the average throughout.

Table No. 1 shows, by seasons, the total precipitation at Eureka, one-half of the total, and the date on which the total since the preceding July 1 amounted to one-half of the total for the entire season. A study of this table reveals some interesting facts, viz:

TABLE 1

Season	Total precipitation for season	One-half total	Date on which one-half of total had been received	Season	Total precipitation for season	One-half total	Date on which one-half of total had been received
1887–88	34.47	17.23	Jan. 30	1909–10	40.36	20.18	Dec. 9
1888–89	34.14	17.07	Feb. 25	1910–11	32.09	16.04	Jan. 19
1889–90	74.10	37.05	Jan. 23	1911–12	38.70	19.35	Feb. 7
1890–91	35.41	17.70	Feb. 23	1912–13	36.03	18.01	Jan. 9
1891–92	38.14	19.07	Jan. 8	1913–14	37.32	18.66	Jan. 16
1892–93	49.17	24.58	Feb. 4	1914–15	42.42	21.21	Jan. 11
1893–94	55.20	27.60	Jan. 13	1915–16	39.99	20.00	Jan. 15
1894–95	45.97	22.98	Jan. 12	1916–17	31.36	15.68	Jan. 29
1895–96	52.45	26.22	Feb. 28	1917–18	24.34	12.17	Feb. 5
1896–97	51.10	25.55	Feb. 1	1918–19	39.80	19.90	Fec. 5
1897–98	35.12	17.56	Jan. 19	1919–20	23.95	11.98	Feb. 21
1898–99	35.72	17.86	Feb. 1	1920–21	48.81	24.40	Dec. 30
1899–1900	51.73	25.86	Dec. 30	1921–22	34.76	17.38	Feb. 9
1900–1901	47.58	23.79	Jan. 2	1922–23	25.18	12.59	Dec. 27
1901–02	51.96	25.98	Feb. 10	1923–24	20.72	10.36	Dec. 18
1902–03	51.73	25.86	Jan. 21	1924–25	41.50	20.75	Jan. 13
1903–04	65.21	32.60	Feb. 16	1925–26	26.78	13.39	Jan. 2
1904–05	32.74	16.37	Dec. 30	1926–27	50.58	25.29	Jan. 2
1905–06	38.50	17.90	Feb. 14	1927–28	30.71	15.36	Feb. 3
1906–07	50.54	25.27	Feb. 2	1928–29	29.40	14.70	Dec. 27
1907–08	35.99	18.00	Jan. 13	1929–30	23.53	11.77	Jan. 17
1908–09	42.96	21.48	Jan. 17				

Average date to which one-half of seasonal total has fallen, Jan. 21.
Earliest date with one-half of total seasonal recorded, Dec. 9, 1909.
Latest date with half of total recorded, Feb. 28, 1896.
Number of times earlier than Dec. 28, 4.
Number of times later than Feb. 14, 4.

1. The average date on which the halfway point in seasonal precipitation is reached is January 21.

2. One-half of the seasonal total has been recorded as early as December 9 (in 1909).

3. One-half of the seasonal total has occurred after February 28 (1896).

4. The season of 1895–96 was a wet one with a total precipitation of 52.45 inches, one-half of which fell after February 28.

The season of 1899–1900 was also a wet one with a total precipitation of 51.73 inches, but in this case one-half of the total amount was recorded before December 30.

5. In the dry season of 1919–20 (total 23.96 inches) one-half of the total amount fell after February 21. In the dry season of 1923–24 (total 20.72 inches) one-half of the total precipitation was recorded before December 18.

From the foregoing the conclusion is reached that more progress might be made if investigators would shorten the period for which they seek to make precipitation forecasts by means of ocean temperatures, etc. Accurate forecasts for even so short a period as two or three months would be of great value and it would seem that success in the making of such forecasts should be more easily attained than if the prediction attempts to cover an entire season, which, as we have seen, may be composed of a very wet part and a very dry part, such radically differing conditions certainly not resulting from the same cause and, therefore, not being predictable from the same data.

STORY TOLD BY THE TREE RINGS IS COMPLICATED BY THE DROUGHT [1]

The time-honored method of telling the ages of trees by the annual rings has been upset this year by the peculiarity of the season, says the Forest Service. Trees in most sections got off to a good start in the spring but were halted by the parching summer drought. Almost everywhere the growth of trees this year has been slight, but in some areas where late summer rains soaked the earth, a second period of growth followed the drought, and so altered the ring records. This has been the case in Alabama, according to reports from the State forester.

When a tree puts on a year's growth it adds a new ring of wood, and the diameter increases by double the thickness of the last tree rings. The age of a tree can therefore usually be told by counting the rings on the stump. As a consequence of the halting and the new advance in growth this season, Alabama trees in many cases put on a second thin layer, known to foresters as a "false ring." So the foresters of future years will have to be on their guard in computing ages in the living calendars of Alabama tree stumps. Such false rings are not uncommon over long periods of years.

This year's regular ring in most parts of the country shows much less thickness than the average year's ring, and even in those regions where growth was renewed late in the season the second ring has not resulted in a larger total year's growth. Most regions, however, did not get rain early enough to start the second ring.

REVISION OF WEATHER BUREAU PRECIPITATION NORMALS (MONTHLY WEATHER REVIEW SUPPLEMENT NO. 34)

The daily, monthly, and annual precipitation normals for the first-order stations of the United States Weather Bureau have been revised and the revised normals published in MONTHLY WEATHER REVIEW SUPPLEMENT No. 34, issued during the latter part of 1930.

The revision is based upon the 50-year period, January 1, 1878, to December 31, 1927. Ninety-six of the

[1] Reprinted from the Official Record, U. S. Department of Agriculture, Jan. 1, 1931.

present first-order stations had complete records for the entire period and the remaining 101 stations, many of which had records for 20, 30 and 40 years, were reduced to the basic period either by interpolating the monthly amounts for the missing years directly from charts of monthly totals of precipitation or by correcting the shorter periods to the full 50 years by the usual methods of comparison with the data from near-by stations. The total number of stations is 197.

The SUPPLEMENT also contains for each station the consecutive 14-day sums of the actual unsmoothed precipitation, from the beginning of January to the last fortnight of the year, which naturally contains 15 days.

An error is noted on page 30 (Erie, Pa.), viz, the annual total given as 39.36 inches should be 36.93 inches.—*A. J. H.*

RAINFALL OF 1930 IN ALASKA

Whereas extreme drought prevailed over large areas in continental United States during 1930, the Territory of Alaska seems to have had generous rains. Rainfall measurements in that Territory have not given, as yet, dependable averages except at individual stations. The rainfall on the average for Alaska during 1930, as computed from stations having a full year's record, may be placed at 34.42 inches; that amount is considerably more than the probable annual average for the Territory. A recent contribution to this REVIEW [2] places the mean annual precipitation of fully two-thirds of the Territory at less than 20 inches. It may be remembered that the precipitation of Alaska is heaviest along the southeast coast and lightest in the interior valleys; thus the mean for coastal Alaska at Juneau is 81.6 inches, and for Fairbanks, near the Yukon, but 11.7 inches. The departure from these means for 1930 was +15.8 inches for Juneau and +5.3 for Fairbanks.—*H. C. Hunter.*

THE INTERNATIONAL ICE PATROL SEASON OF 1930 [3]

The United States Coast Guard is gradually accumulating meteorological and oceanographic data for the region of the Grand Banks that must be of the greatest value to future students of navigation in that fog and ice infested region. The report for 1930 is already at hand and fully measures up to the standard set for previous years.

Icebergs in 1930 appeared off the Grand Banks of Newfoundland very much earlier than usual; accordingly, on February 11, the *Tampa* left Boston, Mass., in obedience to orders from United States Coast Guard headquarters, to make an ice-observation cruise. The *Tampa* reached the Tail of the Grand Banks 48 days earlier in the year than the first ice-patrol vessel did in 1929. The *Tampa* was relieved of the patrol duty by the *Mojave* on February 27, and the last-named in alternation with the *Modoc*, took on the patrol work for the remainder of the season.

In May there were remarkably few bergs off the eastern edge of the Grand Banks. This failure of berg supply, as much as anything else, caused the extraordinarily ice-free conditions that were enjoyed south of the forty-sixth parallel throughout the remainder of the season. The season closed on June 10, unusually early.

Capt. Cecil M. Gabbett, commanding the Ice Patrol, commenting on the season remarks as follows:

> There was a marked deficiency of ice south of the Tail of the Grand Banks, as in 1927 and 1928. In 1930, only six different bergs drifted south of the forty-third parallel, the latitude of the Tail. This small number can be attributed partly to the unusually small amount of field ice reported this year from southeast of Newfoundland and partly to the narrowness of the southward-flowing cold stream off the eastern edge of the Grand Banks. Both of the above factors in turn doubtless depend upon the winds and the weather conditions that prevailed north of Newfoundland and Labrador during the preceding winter months. * * * After May 24 no bergs were sighted or reported, except north of the Grand Banks and along the Newfoundland coast in the vicinity of Cape Race and St. John's.
>
> Throughout the season, the usual extension of cold water to the westward around the Tail of the Banks was largely absent.—A. J. H.

Temperature and visibility data are given in the subjoined table.

Temperature (F.) and visibility during International Ice Patrol, 1930

	Feb.	Mar.	Apr.	May	June [1]
Maximum	44	59	55	67	[1] 70
Minimum	25	22	29	36	37
Mean	33.3	39.6	39.6	47.1	51.6
Visability less than 2 miles, per cent of time	3	26.4	25.8	30.5	40.6

[1] For June 1–12 only.

SIMPLIFIED FORMULAS FOR RAINFALL INTENSITY [4]

By C. E. GRUNSKY

Subsequent to the publication of the simplified formulas for rain intensity in the MONTHLY WEATHER REVIEW of October, 1930, the writer's attention was called to the fact that the information obtained from the observer at Dam No. 4, Nuuanu Valley, Honolulu, was incorrect. The total rain in the 24 hours terminating at 5 p. m. on January 16, 1921, was only 12 inches and not 20 inches. Consequently the illustration is at fault and should be ignored.

However, on the same day 20.15 inches of rain fell at Maunawilli Ranch about 2 miles to the east on the windward side of the mountain.

Furthermore, on November 18, 1930, an automatic recorder belonging to the Geological Survey and situated in Moanalua Valley measured 15.2 inches of rain in three hours and 5.6 inches in one hour.

Based on this rain, the value of C in the appropriate formula should be taken at 5.6 and the probable maximum rain in any single minute was $5.6 = \sqrt[3]{0.0167} = 1.4$ inches.

[2] Fitton, Edith M.: The climates of Alaska, MONTHLY WEATHER REVIEW 58:85–103.
[3] U. S. Treasury—Coast Guard Bulletin No. 20, Washington, 1931, 50 pp., numerous charts and tables.

[4] Supplement to article in the MONTHLY WEATHER REVIEW for October, 1930.

BIBLIOGRAPHY

C. FITZHUGH TALMAN, in charge of Library

RECENT ADDITIONS

The following have been selected from among the titles of books recently received as representing those most likely to be useful to Weather Bureau officials in their meteorological work and studies:

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Weather dominated by solar changes. Washington. 1931. 18 p. figs. 24½ cm. (Smith. misc. coll., v. 85, no. 1.)

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Elm, Ienar Ewald.
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Electrodynamic theory of cyclones and anticyclones. p. 22–23. 29½ cm. (Water works and sewerage. v. 78, Jan., 1931.)

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Un nouveau météorographe pour ballon-sonde. Bruxelles. 1930. 44 p. figs. 29½ cm. (Inst. roy. mét. de Belgique. Mém. v. 3.)

Köppen, W., & Geiger, R., *comp.*
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Le paratonnerre dans les missions et aux colonies. [Bruxelles.] n. d. 32 p. figs. 17½ cm. (Extr.: Rev. miss. des Jésuites belges, Louvain.)

SOLAR OBSERVATIONS

SOLAR RADIATION MEASUREMENTS, FEBRUARY, 1931

By HERBERT H. KIMBALL

For a description of instruments employed and their exposures, the reader is referred to page 41 of this volume of the REVIEW.

Table I shows that solar radiation intensities averaged above the normal intensity for February at Washington, D. C., and below normal at Madison, Wis., and Lincoln, Nebr. Both these stations reported much dense local smoke during the month.

Table 2 shows an excess in the total solar radiation received on a horizontal surface directly from the sun and diffusely from the sky at Lincoln, Chicago, and New York, and a deficiency at all other stations, which was pronounced at Fresno and Pittsburgh.

Skylight polarization measurements were obtained at Washington on seven days, and give a mean percentage of 61, with a maximum of 64 on the 25th. These are close to the corresponding averages for Washington in February. No measurements were obtained at Madison during this month, as the groundwas continuously covered with snow.

TABLE 1.—*Solar radiation intensities during February, 1931*

[Gram-calories per minute per square centimeter of normal surface]

Washington, D. C.

Date	Sun's zenith distance: 8 a.m.	78.7°	75.7°	70.7°	60.0°	0.0°	60.0°	70.7°	75.7°	78.7°	Noon
	75th mer. time	Air mass: A. M.					P. M.				Local mean solar time
	e.	5.0	4.0	3.0	2.0	1.0	2.0	3.0	4.0	5.0	e.
	mm.	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*mm.*
Feb. 3	1.60	0.76	0.90	1.05	.....	.....	1.26	1.04	0.88	0.74	2.06
Feb. 4	3.45	.....	.....	.....	.....	.....	1.14	1.05	0.89	0.69	4.37
Feb. 5	2.49	0.78	0.94	0.97	1.17	.....	.....	1.02	0.80	0.70	2.16
Feb. 10	2.36	0.83	0.94	1.06	1.26	.....	.....	.....	.....	.....	1.78
Feb. 11	1.45	0.85	0.93	1.00	1.19	.....	1.13	0.95	0.86	0.75	1.37
Feb. 24	3.63	.....	.....	.....	.....	.....	1.15	.....	.....	.....	2.74
Feb. 25	2.49	0.90	1.07	1.25	1.27	.....	1.33	1.05	0.87	.....	2.49
Feb. 26	3.30	.....	1.01	1.14	1.28	.....	.....	.....	.....	.....	2.36
Feb. 27	2.62	0.87	0.99	1.15	1.27	.....	1.20	0.98	0.82	.....	1.96
Means	.....	0.83	0.97	1.09	1.24	.....	1.20	1.02	0.85	0.72	.....
Departures	.....	+0.11	+0.16	+0.11	+0.07	.....	+0.01	+0.04	+0.01	−0.04	.....

TABLE 1.—*Solar radiation intensities during February, 1931*—Con.

Madison, Wis.

Date	Sun's zenith distance: 8 a.m.	78.7°	75.7°	70.7°	60.0°	0.0°	60.0°	70.7°	75.7°	78.7°	Noon
	75th mer. time	Air mass: A. M.					P. M.				Local mean solar time
	e.	5.0	4.0	3.0	2.0	[1] 1.0	2.0	3.0	4.0	5.0	e.
	mm.	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*mm.*
Feb. 4	3.30	1.08	1.10	1.26	1.16	.....	.....	.....	.....	.....	3.00
Feb. 5	3.30	0.69	0.83	0.97	1.25	.....	1.16	1.01	.....	.....	3.63
Feb. 10	1.37	0.65	0.77	0.98	1.23	.....	1.26	0.72	.....	.....	1.60
Feb. 11	2.87	.....	.....	.....	.....	.....	1.15	.....	.....	.....	3.45
Feb. 13	2.62	1.00	1.11	1.24	1.43	1.64	1.46	.....	.....	.....	1.37
Feb. 14	1.12	1.05	1.11	1.29	1.41	.....	1.35	.....	.....	.....	1.24
Feb. 21	3.81	.....	0.55	0.79	1.11	.....	.....	.....	.....	.....	3.63
Feb. 25	4.75	.....	.....	.....	.....	.....	1.36	1.21	.....	.....	3.63
Feb. 26	3.45	0.97	1.09	1.22	1.41	1.60	1.34	.....	.....	.....	2.36
Means	.....	0.91	0.94	1.11	1.29	(1.62)	1.30	0.98	.....	.....	.....
Departures	.....	−0.03	−0.14	−0.09	−0.07	.....	−0.06	−0.19	.....	.....	.....

Lincoln, Nebr.

Feb. 2	3.81	0.55	0.56	.....	1.37	.....	1.35	1.23	1.10	0 96	5.16
Feb. 3	4.37	0.95	1.09	1.24	1.38	.....	1.35	1.20	1.09	.....	4.37
Feb. 11	3.63	.....	0.85	0.99	1.26	.....	.....	.....	.....	.....	4.17
Feb. 14	1.32	0.85	0.99	1.18	1.31	.....	1.33	1.15	0.96	0.77	1.68
Feb. 19	3.45	.....	.....	.....	.....	.....	1.22	1.03	.....	.....	3.63
Feb. 20	3.15	0.60	0.74	0.88	1.08	.....	.....	.....	.....	.....	3.81
Feb. 27	5.36	.....	0.67	0.78	1.25	.....	.....	.....	.....	.....	4.57
Means	.....	0.74	0.82	1.01	1.28	.....	1.31	1.15	1.05	(0.86)	.....
Departures	.....	−0.17	−0.20	−0.17	−0.09	.....	−0.04	−0.01	+0.02	−0.06	.....

[1] Extrapolated.

TABLE 2.—*Total solar radiation (direct + diffuse) received on a horizontal surface*

[Gram-calories per square centimeter]

Week beginning—	Washington	Madison	Lincoln	Chicago	New York	Twin Falls	Pittsburgh	Gainesville	Fresno	La Jolla	Miami
	Average daily totals										
1931	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.
Jan. 29	217	160	290	135	170	119	316	182	206	240	
Feb. 5	195	209	291	129	135	142	341	245	250	305	
Feb. 12	220	218	260	150	154	115	311	280	251	300	
Feb. 19	226	244	256	142	228	106	314	407	334	222	
	Departures from weekly normals										
Jan. 29	+17	−30	+59	+16	+29	−6	+11	−38	−36		
Feb. 5	−7	±0	+29	+5	−2	+1	+34	−54	+6		
Feb. 12	−6	−10	−20	+10	+4	−39	−8	−56	−24		
Feb. 19	−29	−6	−45	−22	+44	−40	−52	+54	+10		
Accumulated departures on Feb 26	+280	−966	+560	+126	+1,050	+21	−77	−350	+154		

POSITIONS AND AREAS OF SUN SPOTS

[Communicated by Capt. J. F. Hellweg, Superintendent United States Naval Observatory. Data furnished by Naval Observatory, in cooperation with Harvard, Yerkes, Perkins, and Mount Wilson Observatories The differences of longitude are measured from central meridian, positive west. The north latitudes are plus. Areas are corrected for foreshortening and are expressed in millionths of sun's visible hemisphere. The total area, including spots and groups, is given for each day in the last column]

Date	Eastern standard civil time	Heliographic: Diff. long.	Heliographic: Longitude	Heliographic: Latitude	Area: Spot	Area: Group	Total area for each day
1931	h m	°	°	°			
Feb. 1 (Naval Observatory)	11 9	No spots					
Feb. 2 (Naval Observatory)	11 41	−80.0	213.4	+10.0		62	62
Feb. 3 (Naval Observatory)	11 38	−65.0	215.3	+10.5		231	
		−44.5	235.8	−10.5	6		237
Feb. 4 (Naval Observatory)	11 38	−50.0	217.1	+9.5		154	
		−28.0	239.1	−12.0	9		
		+68.0	335.1	+8.0		12	175
Feb. 5 (Naval Observatory)	11 44	−38.0	215.9	+10.0		201	
		−12.0	241.9	−12.5	3		204
Feb. 6 (Naval Observatory)	11 46	−23.5	217.2	+10.0		262	
		−10.5	230.2	−31.5	3		265
Feb. 8 (Yerkes Observatory)	16 6	+5.3	217.3	+8.9		326	
		+4.0	216.0	+10.0	102		428
Feb. 9 (Mount Wilson)	11 30	−89.0	112.3	+8.0	16		
		+16.0	217.3	+9.0		214	
		+41.0	242.3	−16.0		8	
		+55.0	256.3	−14.0		18	256
Feb. 10 (Naval Observatory)	11 51	+30.0	218.0	+9.0		108	
		+87.5	275.5	−12.5		62	170
Feb. 11 (Naval Observatory)	12 28	−63.0	111.5	+9.0		15	
		+45.0	219.5	+5.0		62	77
Feb. 12 (Naval Observatory)	12 46	−45.0	116.1	+8.0		62	
		+59.0	220.1	+5.0	46		108
Feb. 13 (Yerkes Observatory)	12 34	−35.0	113.1	+6.3		52	
		−30.2	117.9	+6.2		57	
		+67.8	215.9	+7.7	82		191
Feb. 14 (Naval Observatory)	12 43	−80.0	54.8	+0.1	15		
		−79.0	55.8	+8.5	12		
		−18.0	116.8	+4.0		59	86
Feb. 15 (Naval Observatory)	11 32	−70.0	52.3	+9.0		46	
		−66.0	56.3	+0.1		46	
		−10.0	112.3	−7.5		25	
		−2.0	120.3	+4.0	6		
		+4.5	126.8	+3.0	3		
		+12.0	134.3	+10.5	6		132
Feb. 16 (Naval Observatory)	14 39	−57.5	49.9	−16.0		62	
		−50.0	57.4	−22.0		77	
		+15.0	122.4	+8.0	12		
		+18.0	125.4	+11.0	15		166
Feb. 17 (Mount Wilson)	13 50	−42.5	52.2	+6.0		219	
		−37.5	57.2	−4.0		147	
		+42.0	136.7	+12.0		103	469
Feb. 18 (Mount Wilson)	13 55	−27.5	54.0	+6.0		349	
		−24.0	57.5	−3.0	149		
		+57.0	138.5	+12.0		31	529

POSITIONS AND AREAS OF SUN SPOTS—Continued

Date	Eastern standard civil time	Heliographic: Diff. long.	Heliographic: Longitude	Heliographic: Latitude	Area: Spot	Area: Group	Total area for each day
1931	h m	°	°	°			
Feb. 19 (Mount Wilson)	13 15	−14.5	54.2	+6.0		1,265	
		−10.0	58.7	−3.0		153	
		0.0	68.7	+9.0		71	
		+67.0	135.7	+12.0		4	1,493
Feb. 20 (Mount Wilson)	14 10	+1.0	56.0	+7.0		1,571	
		+4.0	59.0	−3.0		42	
		+15.0	70.0	+9.0		40	1,653
Feb. 21 (Naval Observatory)	12 39	+15.0	57.7	−7.0		123	
		+17.5	60.2	+5.0		1,389	
		+28.0	70.7	+7.5		77	1,589
Feb. 22 (Naval Observatory)	11 37	−45.0	75.0	+12.5		247	
		+26.0	56.0	−5.0		370	
		+28.0	58.0	+5.5		1,389	
		+40.0	70.0	+7.5		15	2,021
Feb. 23 (Naval Observatory)	12 5	−65.0	311.7	+10.0		77	
		−30.0	346.7	+13.5		154	
		+40.0	56.7	−5.5		463	
		+42.0	58.7	+7.5		1,080	1,774
Feb. 24 (Naval Observatory)	11 33	−50.0	313.8	+11.0		77	
		−16.0	347.8	+12.5		185	
		+53.0	56.8	−5.0		309	
		+55.0	58.8	+7.0		926	1,497
Feb. 25 (Naval Observatory)	12 12	−85.0	265.3	−3.5		62	
		−38.0	312.3	+1.5		93	
		−1.0	349.3	+11.5		185	
		+26.0	16.3	+10.5	6		
		+67.0	57.3	−6.5		216	
		+68.0	58.3	+6.0		525	1,087
Feb. 26 (Naval Observatory)	11 33	−69.0	268.4	−4.0		154	
		−45.0	292.4	+10.0		93	
		−22.0	315.4	+9.0	9		
		+13.0	350.4	+10.5		154	
		+38.0	15.4	+9.5		62	
		+77.0	54.4	+6.0		216	
		+80.0	57.4	−7.0		247	935
Feb. 27 (Naval Observatory)	11 37	−55.0	269.2	−4.0		154	
		−31.0	293.2	−10.5	3		
		−30.0	294.2	+9.0		62	
		−5.0	319.2	+8.0	6		
		+22.0	346.2	+11.5		46	
		+29.0	353.2	+8.0	12		
		+52.0	16.2	+8.5		31	314
Feb. 28 (Naval Observatory)	11 32	−40.0	271.1	−5.0		247	
		+4.0	315.1	+9.0	3		
		+42.0	353.1	+7.5	9		
		+63.0	14.1	+9.0	31		290
Mean daily area for February							600

PROVISIONAL SUN-SPOT RELATIVE NUMBERS FOR FEBRUARY, 1931

[Data furnished through the courtesy of Prof. W. Brunner, University of Zurich, Switzerland]

(Dependent alone on observations at Zurich and its station at Arosa)

February, 1931	Relative numbers	February, 1931	Relative numbers	February, 1931	Relative numbers
1	0	11	20	21	96
2	8	12	Ec 20	22	
3	d 28	13	23	23	100
4		14	Ecd 19	24	92
5	25	15	41	25	a 68
6	29	16	44	26	d 82
7	19	17		27	72
8	a 27	18	45	28	47
9	29	19			
10	28	20	ab		

Mean: 23 days=41.8.

a=Passage of an average-sized group through the central meridian.
b=Passage of a large group through the central meridian.
c=New formation of a large or average-sized center of activity: E, on the eastern part of the sun's disk; W, on the western part; M, in the central zone.
d=Entrance of a large or average-sized center of activity on the east limb.

AEROLOGICAL OBSERVATIONS

By L. T. SAMUELS

Free-air temperatures during February were considerably above normal at all levels at Ellendale, the northernmost station. (See Table 1.) Positive departures of appreciable magnitude occurred also at Royal Center and Broken Arrow. Negative departures occurred at all levels at Due West and in the higher levels at Groesbeck.

Free-air relative humidities were considerably above normal at Broken Arrow, especially in the higher levels. This fact together with the positive temperature and vapor pressure departures at this station are of special significance in view of the appreciable excess over normal of the total precipitation for the month. Free-air vapor pressures averaged mostly above normal at the other stations excepting Due West.

The resultant free-air wind directions at the 1,000-meter level were mostly northwesterly east of the Rocky Mountains except in the extreme south where they were southerly. Along the North Pacific coast they were variable with a southerly component predominating at the more northerly stations.

At 3,000 meters the resultant direction was strikingly uniform from the west-northwest at practically all stations in the country with a marked northerly component at San Francisco and Modena.

Free-air resultant velocities decreased from the northern to southern stations with lowest values in the Rocky Mountain region.

TABLE 1.—*Free-air temperatures, relative humidities, and vapor pressures during February, 1931*

TEMPERATURE (°C.)

Altitude m. s. l. (meters)	Broken Arrow, Okla. (233 meters)		Due West, S. C. (217 meters)		Ellendale, N. Dak. (444 meters)		Groesbeck, Tex. (141 meters)		Royal Center, Ind. (225 meters)	
	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal
Surface	6.6	+1.7	5.8	−2.0	−3.1	+6.6	12.0	+2.2	1.5	+3.0
500	6.3	+2.5	6.3	−0.8	−3.2	+6.5	10.8	+2.2	0.0	+3.5
1,000	5.6	+2.6	4.9	−0.6	−1.8	+6.8	8.5	+0.2	−1.8	+2.7
1,500	3.4	+1.3	2.8	−0.8	−2.7	+5.4	6.5	−0.6	−2.3	+3.1
2,000	1.1	+0.6	0.9	−0.8	−4.5	+5.0	4.8	−0.3	−3.8	+3.0
2,500	−1.2	+0.6	−1.5	−0.8	−6.9	+4.9	2.0	−0.7	−5.7	+3.0
3,000	−3.4	+1.0	−4.1	−0.9	−9.8	+4.7	−4.4	−4.7	−7.8	+3.4
4,000	−10.2	−0.6	−10.7	−1.7	−15.4	+4.4	−9.9	−5.4	−12.9	+4.3
5,000	−16.4	−1.1	------	------	−21.7	+3.9	------	------	−19.4	------

TABLE 1.—*Free-air temperatures, relative humidities, and vapor pressures during February, 1931*—Continued

RELATIVE HUMIDITY (%)

Altitude m. s. l. (meters)	Broken Arrow, Okla. (233 meters)		Due West, S. C. (217 meters)		Ellendale, N. Dak. (444 meters)		Groesbeck, Tex. (141 meters)		Royal Center, Ind. (225 meters)	
	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal
Surface	75	+6	76	+7	82	+1	80	+6	78	0
500	68	+2	68	+4	81	+1	76	+8	76	−2
1,000	62	+5	64	+4	63	−7	71	+13	73	+3
1,500	63	+12	60	+4	53	−9	65	+14	57	−5
2,000	62	+16	50	−3	50	−9	56	+10	54	−2
2,500	59	+15	44	−7	49	−10	53	+9	53	−1
3,000	56	+13	46	−3	49	−9	49	+7	55	0
4,000	57	+16	46	0	36	−19	42	+5	57	0
5,000	55	+16	------	------	34	−24	------	------	58	------

VAPOR PRESSURE (*mb.*)

Surface	7.51	+1.27	7.28	−0.62	4.14	+1.55	11.29	+1.80	5.34	+0.82
500	6.73	+1.25	6.85	−0.19	4.01	+1.47	9.99	+1.85	4.70	+0.77
1,000	5.81	+1.42	5.79	−0.23	3.37	+1.05	8.08	+1.48	3.88	+0.66
1,500	5.05	+1.47	4.64	−0.22	2.63	+0.56	6.49	+1.34	2.94	+0.40
2,000	4.13	+1.31	3.29	−0.50	2.18	+0.45	4.95	+0.94	2.53	+0.52
2,500	3.36	+1.04	2.36	−0.57	1.78	+0.36	4.14	+0.90	2.14	+0.48
3,000	2.90	+1.01	2.05	−0.21	1.40	+0.29	3.56	+0.88	1.87	+0.53
4,000	1.92	+0.61	1.67	+0.43	0.50	−0.17	2.92	+1.16	1.50	+0.67
5,000	1.14	+0.34	------	------	0.16	−0.22	------	------	1.24	------

TABLE 2.—*Free-air data obtained by airplanes at naval air stations during February, 1931*

Altitude, m. s. l. (meters)	Temperature (°C.)				Relative humidity (%)			
	Hampton Roads, Va.	Pensacola, Fla.	San Diego, Calif.	Washington, D. C.	Hampton Roads, Va.	Pensacola, Fla.	San Diego, Calif.	Washington, D. C.
Surface	2.2	9.8	15.0	−0.5	68	82	65	79
500	2.4	10.3	13.5	1.4	57	73	65	60
1,000	0.9	7.7	11.2	−0.3	47	76	62	54
2,000	−0.9	4.0	5.2	−3.5	28	59	55	45
3,000	−4.4	−0.6	0.7	−7.5	18	46	38	55

TABLE 3.—*Free-air resultant winds (meters per second) based on pilot balloon observations made near 7 a. m. (E. S. T.) during February, 1931*

Altitude, m. s. l. (meters)	Broken Arrow, Okla. (233 meters)		Brownsville, Tex. (12 meters)		Burlington, Vt. (132 meters)		Cheyenne, Wyo. (1,873 meters)		Due West, S. C. (217 meters)		Ellendale, N. Dak. (444 meters)		Groesbeck, Tex. (139 meters)		Havre, Mont. (762 meters)		Jacksonville, Fla. (14 meters)		Key West, Fla. (11 meters)		Los Angeles, Calif. (127 meters)		Medford, Oreg. (410 meters)	
	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity
	°		°		°		°		°		°		°		°		°		°		°		°	
Surface	S 31 E	1.0	S 40 E	0.7	S 16 W	0.7	N 78 W	2.6	N 33 E	0.8	N 67 W	1.3	N 7 E	0.6	S 60 W	2.5	N 34 W	0.9	N 52 E	2.0	N 51 E	2.3	S 5 E	0.3
500	S 16 E	3.7	S 51 E	4.3	S 85 W	2.4	------	---	N 22 W	0.8	N 63 W	1.8	S 34 W	1.9	------	---	S 53 E	0.7	N 74 E	3.5	S 75 E	3.6	N 54 E	0.2
1,000	S 43 W	3.6	S 9 E	4.8	N 80 W	5.4	------	---	N 78 W	3.0	N 62 W	4.4	S 80 W	2.5	S 69 W	6.4	S 68 W	1.9	S 54 E	2.6	S 63 E	2.9	S 5 W	1.4
1,500	S 86 W	3.1	S 28 W	4.9	N 44 W	7.4	------	---	N 75 W	4.4	N 67 W	6.0	N 71 W	1.5	S 86 W	7.8	N 87 W	2.7	S 53 W	1.8	S 49 E	2.0	S	2.6
2,000	S 89 W	3.9	N 89 W	2.5	N 36 W	10.7	N 76 W	4.1	N 68 W	6.3	N 67 W	6.8	N 69 W	2.9	N 84 W	7.7	N 80 W	5.0	S 85 W	3.6	S 73 E	1.6	S 52 W	2.9
2,500	N 86 W	4.0	N 64 W	7.2	N 38 W	11.8	N 73 W	5.8	N 65 W	7.7	N 61 W	8.4	N 64 W	4.2	N 77 W	6.8	N 89 W	7.8	N 81 W	5.1	N	3.6	S 62 W	4.1
3,000	N 61 W	3.5	N 77 W	6.8	N 43 W	13.6	N 71 W	5.8	N 71 W	9.7	N 51 W	9.9	N 76 W	7.5	N 82 W	5.4	N 70 W	7.7	N 76 W	5.2	------	---	S 75 W	3.1
4,000	------	---	------	---	------	---	N 70 W	6.1	N 72 W	14.6	N 80 W	10.1	N 88 W	9.9	------	---	N 73 W	13.0	N 85 W	10.0	------	---	N 81 W	2.5
5,000	------	---	------	---	------	---	N 47 W	2.9	N 82 W	18.5	------	---	------	---	------	---	------	---	N 89 W	13.6	------	---	------	---

TABLE 3.—*Free-air resultant winds (meters per second) based on pilot balloon observations made near 7 a. m. (E. S. T.) during February, 1931*—Continued.

Altitude (meters) m. s. l.	Memphis, Tenn. (145 meters)		Modena, Utah (1,665 meters)		New Orleans, La. (25 meters)		Omaha, Nebr. (299 meters)		Phoenix, Ariz. (356 meters)		Royal Center, Ind. (225 meters)		Salt Lake City, Utah (1,294meters)		San Francisco, Calif. (8 meters)		Sault Ste. Marie, Mich. (198 meters)		Seattle, Wash. (14 meters)		Spokane, Wash. (606 meters)		Washington, D. C. (10 meters)	
	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity
	°		°		°		°		°		°		°		°		°		°		°		°	
Surface	N 63 E	0.4	N 69 W	0.2	N 65 E	0.9	S 51 E	1.1	S 76 E	2.8	S 88 W	0.4	S 55 E	0.5	N 80 E	1.2	N 61 W	0.5	S 38 E	0.9	S 12 E	1.0	N 24 W	1.0
500	N 36 W	1.4	----------	---	S 59 E	2.0	S 19 W	1.6	S 73 E	2.6	N 63 W	3.3	----------	---	N 11 E	1.6	N 9 W	1.6	S 2 W	4.7	----------	---	N 46 W	5.9
1,000	N 45 W	4.0	----------	---	N 84 W	2.2	S 78 W	3.6	S 48 E	0.7	N 48 W	5.3	----------	---	N 3 E	1.9	N 34 W	5.0	S 20 W	4.4	S 2 E	2.5	N 52 W	8.3
1,500	N 41 W	5.8	----------	---	N 68 W	3.5	N 76 W	5.1	S 19 E	1.5	N 60 W	7.4	S 37 E	1.0	N 47 W	1.0	N 33 W	6.0	S 35 W	4.8	S 36 W	3.7	N 56 W	11.0
2,000	N 51 W	5.8	N 32 E	1.6	N 73 W	4.2	N 62 W	5.7	S 11 W	2.2	N 62 W	8.9	S 3 E	2.1	N 16 W	3.5	N 32 W	8.4	S 22 W	4.4	S 49 W	3.4	N 50 W	10.9
2,500	N 38 W	5.6	N 53 E	1.8	N 58 W	4.4	N 68 W	6.2	S 40 W	2.6	N 64 W	8.9	S 31 W	1.8	N 18 W	5.3	N 39 W	11.7	S 50 W	3.4	S 54 W	4.0	N 51 W	12.2
3,000	----------	---	N 8 W	1.4	N 82 W	6.2	N 70 W	7.8	S 76 W	2.5	N 74 W	8.2	S 77 W	1.4	N 34 W	5.4	N 41 W	11.2	----------	---	S 72 W	4.0	N 59 W	11.0
4,000	----------	---	N 59 W	4.7	----------	---	N 76 W	8.8	N 88 W	4.9	----------	---	S 53 W	3.8	----------	---	----------	---	----------	---	S 23 W	4.0	----------	---
5,000	----------	---	N 34 W	7.4	----------	---	----------	---	----------	---	----------	---	----------	---	----------	---	----------	---	----------	---	----------	---	----------	---

TABLE 4.—*Observations by means of kites, captive and limited height sounding balloons during February, 1931*

	Broken Arrow, Okla.	Due West, S. C.	Ellendale, N. Dak.	Groesbeck, Tex.	Royal Center, Ind.
Mean altitudes, meters m. s. l., reached during month	2,822	2,636	3,193	2,492	2,852
Maximum altitude, meters m. s. l., reached	5,416	4,149	5,197	4,560	5,352
Number of flights made	28	30	26	19	27
Number of days on which flights were made	26	28	25	19	26

In addition to the above, there were approximately 176 scheduled pilot balloon observations made daily at 60 Weather Bureau stations in the United States.

WEATHER IN THE UNITED STATES

THE WEATHER ELEMENTS

By M. C. BENNETT

GENERAL SUMMARY

February was much warmer than normal in nearly all sections of the country. Along the Atlantic and Gulf coasts temperatures were near the average, but in Florida they were slightly below. In the Ohio Valley the month averaged from 4° to 8° warmer than normal, the central Mississippi Valley from 8° to 11° warmer, and from Iowa and Nebraska northward and northwestward, the plus departures were from 12° to more than 20°.

The precipitation during the month was very unevenly distributed. A large portion of the Southeast received less than half the normal. Light amounts fell also over a belt from the western lake region westward to South Dakota, and in much of the northern Rocky Mountain and the Pacific regions, while the northern portion of the Ohio Valley received from 60 to 75 per cent of normal. Generous amounts were received from southern Missouri, Oklahoma, and the central Rocky Mountain region southward, while the far Southwest received abnormally heavy rains.

TEMPERATURE

The temperature conditions were much like those of January just preceding, but usually February was still warmer than January had been. The first six days of February greatly resembled the last few of January, temperatures being below normal in parts of the Northeast, and about normal in Florida, while some cool weather occurred in the far Northwest; but for most of the country the warmth was noteworthy and very unseasonable, two stations in North Dakota averaging 34° warmer than normal for the week ending February 3.

A cold spell, not severe, appeared about the 8th in the far Northwest, yet was mainly of brief duration, save that after it had spread southward and eastward the southeastern portion of the country was mainly cooler than normal until about the 20th. Meantime, moderately cool weather had set in over the southern Plateau region. The last week was generally cooler than normal in southern sections from New Mexico to the south Atlantic coast, particularly in Texas; but central and northern sections had mild weather for the season all the second half of February, especially the districts between the Lakes and the northern Rocky Mountains.

While February as a whole was decidedly mild in most States, the temperatures were comparatively steady from day to day, with few new records established. The highest marks were generally noted about the 8th in the lower Mississippi Valley and in central sections east of that river, but on the 28th from Michigan and Ohio eastward; while west of the Mississippi River they occurred mainly during the first five days or about the 19th. The lowest readings occurred usually from the 7th in the Pacific Northwest to the 11th in the Atlantic and Gulf States; but in the middle and southern Rocky Mountain region and to westward at various dates.

Of the 37 States from the Plains eastward only 15 recorded temperatures below zero at any time during February, 1931.

Chart No. 1 shows the distribution of mean temperature with respect to the normal.

Much of the upper Missouri Valley found this the warmest February in the whole period of records, which at a few points exceeded 50 years in length.

For most of the central and north-central portions of the country the 3-month winter period, December, 1930, to February, 1931, averaged warmer than, or about equal to, the warmest other like period of record. At St. Paul, Minn., in a record covering 111 consecutive winters, only that of 1877–78 surpassed the mildness of the winter just ended.

PRECIPITATION

The fortnight from the 3d to the 16th was notable for heavy precipitation for the region over most of southern California and Arizona. During the same time well-distributed moderate to heavy rain reached most of the near Southwest, the central valleys and the southern drainage of the Ohio River. Several scattered areas received much precipitation during the last three days of the month.

February, as a whole, brought considerably more moisture than January had, yet for more than half of the country there was less than normal. In many eastern and central districts the precipitation was well distributed through the month and fell at a gentle to moderate rate, the soil thus getting great benefit for the quantity.

The inset on Chart No. V shows the monthly distribution with respect to the normal.

At Cairo, Ill., and Springfield, Mo., the monthly amounts were greater than normal for the first time since January, 1930.

The precipitation of the past winter (December to February, inclusive) is noted as the least of any winter of record at several places in the north-central portion of the country; likewise at some localities in northern California.

SNOWFALL

The snowfall was usually light for February, save in a few States. The middle and southern portions of the Rocky Mountain area mainly had more than normal, while from central North Dakota eastward to New England, the more northern States usually had from one-half to seven-eighths of normal amounts.

The snowfall was light and largely negligible over the southern half of the Middle Atlantic States, practically all of the Ohio Valley, the middle and much of the upper Mississippi Valley, and almost all the Plains. Most of Montana received but very light snowfall, while the Plateau and Pacific States nearly everywhere received much less than normal. When February ended, the stored snow in the elevated portions of the West was in almost every area less than the average quantity and in several States about as little as had ever before been noted at this time of year.

SUNSHINE AND RELATIVE HUMIDITY

Throughout much of the East and Southeast, and the northern portions of the Great Plains more than the normal amount of sunshine was received during the month, while in the Southwest and central Rocky Mountain region and to the westward, much cloudy weather prevailed. Elsewhere, about the usual amount of sunshine was received. The relative humidity was below the normal generally in the Southeast, much of the East, the Missouri Valley and far Northwest, while in the Southwest and the central and southern portions of the Rocky Mountain and Plateau regions it was above normal. The plus departures were rather large in the far Southwest, as would be expected from the abnormal rainfall received in that region.

SEVERE LOCAL STORMS, FEBRUARY, 1931

[The table herewith contains such data as have been received concerning severe local storms that occurred during the month. A more complete statement will appear in the Annual Report of the Chief of Bureau]

Place	Date	Time	Width of path, miles	Loss of life	Value of property destroyed	Character of storm	Remarks	Authority
El Dorado, Kans.	6	10 a. m.	2			Heavy hail	Some damage to wheat; path 14 miles long	Official, U. S. Weather Bureau.
Toledo, Ohio	7	3 a. m.–1:15 p. m.				Ice	Minor damage to trees and wires	Do.
Iowa (southern)	7					Blizzard	Numerous automobile accidents; motor and rail transportation interrupted.	Do.
Canaveral Lighthouse, Fla. (near).	17				$8,000	Winds	4 fishing boats beached	Do.
Sealy, Tex.	28	7 p. m.	4		1,500	Hail	Crops injured	Do.

RIVERS AND FLOODS

By MONTROSE W. HAYES

There were no overflows of importance in February, 1931. In Georgia, especially during the latter half of the month, there was enough rain to cause pronounced rises in the rivers, but bankful stages were not reached and the rises were quite beneficial. Rains in southwestern Missouri and northwestern Arkansas were rather heavy on the 7th and 8th and caused bankful stages in the Black, White, and Petit Jean Rivers. In eastern Texas, also, there was enough rain to materially increase the volume of water carried by the rivers, and at a few places the Trinity overflowed very slightly, without causing any damage. Probably the rises of the greatest importance occurred in Arizona, and are reported by the official in charge of the Weather Bureau office at Phoenix as follows:

As a result of heavy rains in southern Arizona from the 11th to the 16th, flashy rises occurred at a number of places in tributaries of the Gila River and at headwaters of that stream. The Salt River at Phoenix attained a stage of 6.2 feet on the 15th and continued above flood stage, 5.0 feet, on the 16th, the stage on the morning of the 16th being 5.3 feet. The greater part of the water came from the Verde River, a tributary of the Salt. Very little water was received from the Salt, owing to the storage dams on that stream.

Heavy rains in the drainage area of the San Pedro, a tributary of the upper Gila, caused a considerable rise at Kelvin (a short distance below the Coolidge Dam), which reached a height of 6.5 feet on the 16th; after this there was a rapid fall. The flood stage at Kelvin is 5.0 feet.

As little water came from the Hassayampa River, and the greater part of that from the Agua Fria was impounded by the Pleasant Irrigation Dam, there was no marked rise in the lower Gila.

Two men were drowned in the Verde River by the overturning of a boat. Unusually heavy rain at Wellton, near Yuma, was followed by a rush of water from a "wash" near that place. A trestle and some of the roadbed of the Southern Pacific Railway were carried out, causing damage to the extent of about $30,000.

A table of flood stages and crests is given below.

In most of the Mississippi system low river stages still prevail. Usually, low February levels above Cairo are caused by ice, but in the winter just ending there has been less ice than is customary. At Sioux City, Iowa, the channel of the Missouri was not closed at any time. The Sioux City records extend to 1855, and at only one other time, in 1888–89, did the channel remain open through the winter. Early in February the ice had run out of the Missouri as far north as Chamberlain, S. Dak.

The following reports from officials in charge of Weather Bureau offices are considered of interest:

Pittsburgh, Pa.—Precipitation during February was light, but was sufficient during the second and third weeks to create considerable run-off. The smaller tributaries were running strong for several days, and the Ohio at Pittsburgh rose to a stage of 14.4 feet on the 21st—the highest stage since April 23, 1930. Wells, springs, and some small streams that dried up during the fall are running again.

Cincinnati, Ohio.—For the last three months—November, December, and January—the rainfall in and around Cincinnati actually was less than the normal January rainfall alone. This emphasizes the increasing gravity of the situation.

Farmers right now are hauling more water for their suffering stock, and for themselves, than they hauled at the peak of the drought last summer.

Hamilton County commissioners have been informed within the last week that tank wagons are carrying 50,000 gallons of water a day from the county pipe lines to farms and residences without water. An increase to 60,000 gallons daily is imminent.

Memphis, Tenn.—Rivers here are already feeling the effects of the dry weather. The Mississippi River is the lowest in the past 12 years and cargo barges are having difficulty in negotiating narrows and shallows. A majority of the river firms have been loading their barges only to half capacity in order to insure swift and safe trips.

Table of flood stages in February, 1931

River and station	Flood stage	Above flood stage—dates		Crest	
		From—	To—	Stage	Date
MISSISSIPPI DRAINAGE	*Feet*			*Feet*	
Black: Black Rock, Ark	14.0	9	10	15.6	10
White: Batesville, Ark	23.0	9	10	23.8	10
		10	11	20.8	11
Petit Jean: Danville, Ark	20.0	15	16	20.7	15
		24	25	21.3	24
WEST GULF DRAINAGE					
Trinity:					
Dallas, Tex	28.0	25	26	29.4	26
Liberty, Tex	25.0	12	12	25.2	12
PACIFIC DRAINAGE					
Gila: Kelvin, Ariz	5.0	15	16	6.5	16
Salt: Phoenix, Ariz	5.0	15	16	6.2	15

WEATHER OF THE ATLANTIC AND PACIFIC OCEANS

NORTH ATLANTIC OCEAN

By F. A. YOUNG

February is normally one of the stormiest months of the year over the North Atlantic, and the conditions during the current month could not be called exceptional, although there were a number of severe disturbances that will be referred to later. The number of days with gales was not far from normal west of the fortieth meridian, north of the thirtieth parallel, and somewhat below over the middle and eastern sections of the steamer lanes. The North Atlantic HIGH was unusually well developed, as indicated by the large positive departure at Horta, shown in Table 1.

Fog was much more prevalent than during the preceding two months, and the number of days on which it was reported in different localities is as follows. Over the Grand Banks, from 6 to 12 days; along the American coast, between the thirtieth and forty-fifth parallels, from 2 to 5 days; over the steamer lanes between the twentieth and forty-fifth meridians, from 1 to 5 days; along the European coast, from 1 to 3 days; in the Gulf of Mexico, from 1 to 2 days.

TABLE 1.—*Averages, departures, and extremes of atmospheric pressure at sea level, 8 a. m. (seventy-fifth meridian), North Atlantic Ocean February, 1931*

Stations	Average pressure	Departure	Highest	Date	Lowest	Date
	Inches	*Inch*	*Inches*		*Inches*	
Julianehaab, Greenland	29.66	(1)	30.46	27th	29.06	3d.
Belle Isle, Newfoundland	29.87	+[2]0.12	30.66	19th	29.34	28th.
Halifax, Nova Scotia	29.87	−[2]0.04	30.52	8th	29.32	23d.
Nantucket	29.96	−[2]0.04	30.42	7th	29.64	14th.
Hatteras	30.07	−[2]0.04	30.30	12th	29.82	14th.
Key West	30.03	−[2]0.07	30.20	7th	29.82	25th.
New Orleans	30.07	−[2]0.06	30.30	15th	29.76	24th.
Cape Gracias, Nicaragua	29.93	−[2]0.06	29.98	13th [4]	29.86	16th.
Turks Island	30.04	−[2]0.04	30.16	7th [4]	29.84	4th.
Bermuda	29.95	−[2]0.17	30.38	13th	29.30	26th.
Horta, Azores	30.41	+[2]0.28	30.78	12th	30.06	22d.
Lerwick, Shetland Islands	29.54	−[2]0.18	30.32	3d	28.91	20th.
Valencia, Ireland	29.98	+[2]0.06	30.32	3d [4]	29.59	8th.
London	29.92	−[2]0.08	30.37	24th	29.22	16th.

[1] No normal available.
[2] From normal shown on Hydrographic Office Pilot Charts, based on observations at Greenwich mean noon, or 7 a. m., seventy-fifth meridian time.
[3] From normals based on 8 a. m. observations.
[4] And on other date or dates.

On the 1st a fairly deep depression was central near the south coast of Greenland, with a secondary LOW over the North Sea, and moderate gales prevailed over the central section of the steamer lanes and off the west coasts of France and England.

On the 3d there was evidently a redevelopment of the Greenland LOW, and on that date moderate to strong westerly gales occurred in the southerly quadrants. This LOW moved slowly eastward, and on the 5th was central near 52° N., 22° W.

A moderate depression that on the 7th was over the eastern section of the steamer lanes developed into a severe disturbance, as on the 8th vessels near the center reported westerly winds of hurricane force. On the 9th and 10th stormy conditions continued over the central section of the ocean, and on the latter date as well as on the 11th northerly gales were reported west of the seventieth meridian, between the twenty-fifth and fortieth parallels, and from the 10th to 12th heavy weather was also encountered off the west coast of Europe.

On the 13th and 14th moderate conditions prevailed over the ocean as a whole, with the exception of gales over a limited area about 500 miles east of the Bermudas, while on the 13th land stations on the British Isles reported northerly winds of force 7 and 8.

On the 15th Sydney, Nova Scotia, was near the center of a well-developed LOW, and on the same date a secondary was over the Bermudas, while severe gales were encountered by vessels in the intermediate region. According to press reports three vessels were beached, one sunk, and others damaged in the vicinity of Hampton Roads during the storm.

On the 16th and 17th strong to whole northerly gales again prevailed along the coast of Europe, the storm area extending from the forty-fifth to fifty-seventh parallels, while moderate conditions were the rule over the remainder of the ocean.

On the 18th a depression was central about midway between the Azores and Bermudas that increased in intensity as it moved slowly eastward, and on the 19th and 20th gales of force 8 to 10 were encountered by vessels between the thirtieth and fortieth meridians. On the 20th northwesterly gales also occurred over the eastern section of the northern steamer lanes.

Charts VIII and IX show the conditions on the 22d and 23d, respectively, when a very severe and extensive disturbance prevailed over the western section of the ocean. By the 24th this storm had decreased considerably both in extent and intensity, and on the 25th moderate weather prevailed generally.

On the 26th Bermuda was near the center of a LOW that developed into a severe disturbance as shown on Charts X and XI for the 27th and 28th, respectively.

NOTES.—Canadian steamship *City of Vancouver*, Capt. M. Buchanan; Observer, W. A. Kent; from Antwerp to Canal Zone; Feb. 4, 1.45 A. T. S. in 14° 52′ N., 72° 44′ W. Sea appeared to have on a fine layer of dust with occasional irregular lines of what appeared to be yellow sand. These stretched approximately in a north and south direction and extended as far as could be seen on both sides. These conditions continued until about 3 p. m. in 14° 45′ N., 72° 53′ W. Course, S. 52° W.; wind W. S. W., 2; sea slight; swell, easterly, slight; barometer, 29.94 inches; thermometer, 83°; sea temperature, 79.5°.

Mr. C. Desmond, second officer and observer, Honduran steamship *Cuyamapa*, Capt. N. Christiansen, reports as follows:

At 19.55 G. M. T. I observed an exceptionally large waterspout several hundred feet high in latitude 30° 58′ N., longitude 77° 18′ W.

It formed very quietly, no confusion or vapor in vicinity except in itself. It ascended in a straight line, or nearly so, towards the sky to a great height. When heavy dark blue sky lowered in a cone-shape form until it met the ascending water or vapor.

In the center of the globular-shaped moisture, a very light tube formed and continued for 20 minutes. Then it separated at an altitude of a thousand feet, lowered to approximately 500 feet, and took the form of a burning mountain.

With great force these fumes took altitude. The spout, later losing its energy turned to a whirlwind of great interest, about 5 to 10 feet above the surface.

Later heavy showers of rain fell; the wind increased to force 5, veering to the west and northwest, that had been southerly. Barometer, 29.58; air, 66° F.; surface temperature of sea water 71°.

OCEAN GALES AND STORMS, FEBRUARY, 1931

Vessel	Voyage		Position at time of lowest barometer		Gale began	Time of lowest barometer	Gale ended	Lowest barometer	Direction of wind when gale began	Direction and force of wind at time of lowest barometer	Direction of wind when gale ended	Highest force of wind and direction	Shifts of wind near time of lowest barometer
	From—	To—	Latitude	Longitude									
NORTH ATLANTIC OCEAN			° ′	° ′				*Inches*					
Frederik VIII, Dan. S. S.	Oslo	Halifax	56 35 N	28 20 W	Feb. 2	Mdt, 2	Feb. 4	29.47	SSE	SSE, 8	WSW	WSW, 10	SSE-S-SSW.
Milwaukee, Ger. M. S.	New York	Galway	49 45 N	30 00 W	Feb. 3	10 p, 4	Feb. 5	29.47	E	SSW, 10	NW	WNW, 11	E-S-W-NW.
Carlsholm, Swed. S. S.	Fair Island Strait.	Boston	57 59 N	22 24 W	Feb. 4	7 a, 5	do	29.19	W	SSW, 6	WSW	WSW, 12	SE-SW-N.
Ala, Am. S. S.	Antwerp	New York	39 14 N	55 50 W	Feb. 5	1 p, 6	Feb. 6	29.59	S	SSW, 8	NW	S, 9	S-W-NW.
Sinaia, Fr. S. S.	Gibraltar	Providence	39 00 N	42 05 W	do	—, 7	Feb. 8	29.60	SW	Calm	NNE	SSW, 10	
Carlsholm, Sweden	Fair Island Strait.	Boston	54 20 N	36 08 W	Feb. 8	8 a, 8	do	28.70	WSW	WSW, 11	W	WSW, 12	SW-W-NW.
Jean Jadot, Belg. S. S.	New York	Antwerp	41 05 N	50 28 W	do	3 a, 8	Feb. 9	29.96	NW	NW, 9	NW	NW, 10	
Sagaporack, Am. S.S.	Norway	Newport News.	58 28 N	19 17 W	do	Noon, 8	do	28.88	SW	SW, 8	SW	—, 10	SW-WSW.
Santa Marta, Am. S. S.	Canal Zone	New York	33 11 N	74 30 W	Feb. 9	4 a, 10	Feb. 10	29.66	WNW	WNW, 9	NW	—, 9	W-WNW-NW
Boston City, Br. S. S.	New York	Cardiff	51 22 N	3 20 W	Feb. 10	8 p, 12	Feb. 15	29.65	W	NW, 5	NW	WNW, 10	Steady.
United States, Dan. S. S.	Oslo	Halifax	58 08 N	16 30 W	Feb. 14	2 p, 15	Feb. 16	29.38	SSW	NW, 9	N	WNW, 10	SW-W-NW.
Carplaka, Am. S. S.	Gothenburg	Portland, Me.	58 38 N	6 53 W	Feb. 15	4 a, 16	Feb. 17	28.97	W	W, 5	N	N, 10	W-N.
Asia, Dan. M. S.	St. Thomas	Hamburg	33 40 N	41 30 W	Feb. 17	Noon, 17	Feb. 20	30.02	SSE	SSE, 8	S	SSE, 11	S-SSE-SSW.
Carplaka, Am. S. S.	Gothenburg	Portland, Me.	57 19 N	26 30 W	Feb. 18	8 p, 19	do	29.25	W	W, 10	W	W, 10	W-NW.
Liberty, Am. S. S.	Havre	New York	36 14 N	61 58 W	Feb. 21	Mdt, 21	Feb. 23	28.95	WNW	WNW, 4	NW	NW, 12	Steady.
Exmouth, Am. S. S.	Gibraltar	do	36 10 N	53 00 W	do	5 p, 22	Feb. 24	29.04	S	WSW, 11	WNW	—, 11	S-SW.
West Hika, Am. S. S.	Hamburg	Gulfport	30 58 N	62 55 W	do	Noon, 26	Feb. 27	29.17	W	W, 8	NNW	NW, 11	
Cabo Espartel, Span. S. S.	Seville	New York	35 20 N	51 30 W	Feb. 27	1 a, 27	Mar. 1	28.89	WSW	WSW, 6	WNW	NW, 10	
Singkeep, Du. S. S.	Oran	Boston	37 04 N	44 00 W	Feb. 26	7 p, 27	Feb. 28	29.05	SSE	SW, 10	W	—, 11	SW-W.
Wyneric, Br. S. S.	Curacao	Liverpool	38 27 N	40 35 W	do	3 a, 28	do	29.45	SE	SSW, 10	WSW	SE, 11	SSE-S-SW.
President Harrison, Am. S. S.	Gibraltar	New York	42 55 N	50 15 W	Feb. 28	1 a, 28	Mar. 2	28.83	WNW	WNW, 8	NW	NW, 12	
NORTH PACIFIC OCEAN													
Michigan, Am. S. S.	Shanghai	San Francisco	48 00 N	171 15 E	Jan. 31	Noon, 31	Feb. 1	28.03	ENE	SSW, 5	W	WSW, 9	SSE-S-SSW.
Arizona Maru, Jap. S. S.	Seattle	Yokohama	52 07 N	154 42 W	Feb. 1	4 a, 2	Feb. 2	29.17	SSW	SSW, 9	SW	SSW, 9	SSW-S-SW.
Hakutatsu Maru, Jap. S. S.	Miike	San Pedro	45 25 N	158 20 E	do	5 a, 3	Feb. 4	29.22	S	SE, 8	SW	NW, 11	SE-SW.
Do	do	do	48 53 N	176 15 W	Feb. 7	10 a, 7	Feb. 8	28.82	SSE	SSW, 8	SW	WSW, 11	SSW-SW.
Laurel, Swed. M. S.	Port Adelaide	San Francisco	31 37 N	131 50 W	Feb. 1	—, 3	Feb. 6	29.74	N	N, 10	NNW	N, 11	N-NNW.
William Penn, Am. M. S.	Iloilo	San Pedro	33 59 N	153 20 W	Feb. 2	3 p, 2	Feb. 2	29.66	SSE	SSE, 10	S	S, 10	SSE-S.
San Diego Maru, Jap. M. S.	Kudamatsu	Los Angeles	37 10 N	157 05 E	do	4 p. 2	do	29.40	E	E, 9	E	E, 9	SSE-E.
San Luis Maru, Jap. M. S.	Elwood	Kudamatsu	30 02 N	179 50 W	do	8 p, 2	Feb. 3	29.31	S	SW, 7	WNW	W, 9	S-SW-W.
Bessemer City, Am. S.S.	Mobile	Los Angeles	14 04 N	96 15 W	Feb. 3	4 p, 4	Feb. 4	29.95	N	ENE, 9	ENE	N, 11	NE-ENE.
Ryujin Maru, Jap. S. S.	Vancouver	Shanghai	53 05 N	157 15 W	Feb. 2	2 a, 2	Feb. 2	28.86	S	SSW, 9	SW	SSW, 9	S-SW.
Do	do	do	50 28 N	174 55 E	Feb. 8	11 a, 8	Feb. 8	28.82	NE	NNW, 9	NW	NNW, 9	NE-WNW.
Ryoyo Maru, Jap. M. S.	Yokohama	San Francisco	47 25 N	152 10 W	Feb. 4	4 a, 5	Feb. 5	29.11	ESE	ESE	SSW	S, 9	
Kinai Maru, Jap. M. S.	do	Los Angeles	43 40 N	164 00 W	Feb. 7	8 a, 9	Feb. 9	28.97	NE	W, 9	W	W, 9	NW-W.
Pres. Wilson, Am. S. S.	Honolulu	Kobe	30 34 N	143 45 E	Feb. 10	5 p, 10	Feb. 10	29.69	SW	SW, 9	NW	SW, 9	SW-W-NW.
Havana Maru, Jap. S. S.	Otaru	San Francisco	49 11 N	171 35 W	Feb. 12	10 p, 12	Feb. 14	28.44	SE	SSW, 9	WSW	SW, 10	S-SSW-SW.
Forresbank, Br. M. S.	San Pedro	Yokohama	32 43 N	176 18 W	Feb. 15	11 a, 16	Feb. 16	29.74	SSW	SW, 8	WNW	SW, 9	WSW-SW-W.
Mojave, Am. S. S.	Yokohama	San Pedro	39 32 N	174 30 E	Feb. 16	1 a, 18	Feb. 19	29.21	NW	S, 10	W	S, 10	4 points.
Tyndareus, Br. S. S.	do	Victoria	49 40 N	163 55 W	Feb. 17	10 a, 18	Feb. 20	28.07	SE	WSW, 9	W	SW, 9	S-WSW-W.
Forresbank, Br. M. S.	San Pedro	Yokohama	32 23 N	165 51 E	Feb. 18	2 p, 19	Feb. 19	29.59	SW	SW, 8	W	WSW, 9	SW-WSW.
Hakushika Maru, Jap. S. S.	Mobile	Coos Bay	31 54 N	119 28 W	Feb. 19	Mdt, 20	Feb. 21	29.98	NW	WNW, 9	NNW	WNW, 9	Steady.
Do	do	do	38 50 N	124 40 W	Feb. 23	2 p, 23	Feb. 24	30.03	NNW	NNW	N	NNW, 9	Do.
Fukuyo Maru, Jap. S. S.	Japan	Vancouver	48 37 N	178 03 E	Feb. 22	5 a, 23	do	29.49	ESE	NW, 3	W	W, 11	
Batoe, Du. S. S.	Soerabaia	Portland	43 23 N	156 20 W	Feb. 24	8 p, 24	Feb. 25	29.66	S	SW, 8	WNW	W, 10	S-SW-WNW.
Golden Sun, Am. S. S.	Otaru	San Francisco	45 17 N	168 55 E	Feb. 25	8 p, 25	Feb. 27	29.34	ESE	SSE, 7	N	SE, 10	SE-W.

NORTH PACIFIC OCEAN

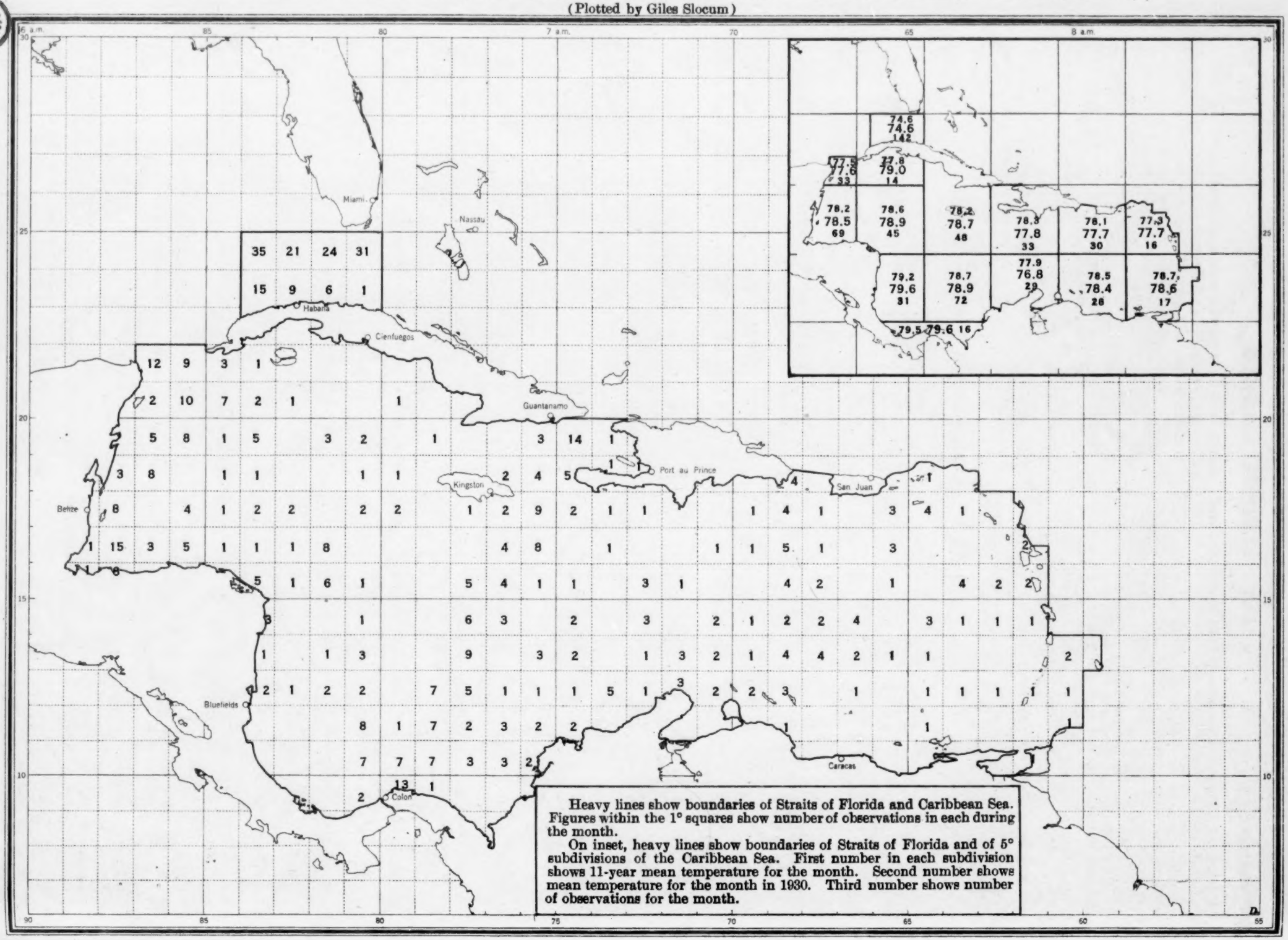
By WILLIS E. HURD

Atmospheric pressure.—Over the eastern half of the North Pacific Ocean, except the southeastern part, particularly along the California coast, atmospheric pressure rose in February, following the extraordinarily low barometer covering the upper waters during January, although still below the normal from Juneau westward into the Aleutians. The Aleutian cyclone, central in January near Dutch Harbor, fluctuated to the eastward in February, with an average near-central pressure of 29.23 inches at Kodiak. In this general region the cyclonic activity was greatest and the pressure lowest during the early half of the month.

UNIV. OF ILL.

Distribution of Greenwich Mean Noon Bucket Observations of Sea Surface Temperatures, February, 1930

(Plotted by Giles Slocum)



Heavy lines show boundaries of Straits of Florida and Caribbean Sea. Figures within the 1° squares show number of observations in each during the month.

On inset, heavy lines show boundaries of Straits of Florida and of 5° subdivisions of the Caribbean Sea. First number in each subdivision shows 11-year mean temperature for the month. Second number shows mean temperature for the month in 1930. Third number shows number of observations for the month.

The North Pacific anticyclone was especially well developed in midocean throughout February. Between California and the Hawaiian Islands cyclonic disturbances related to the northern LOW system prevailed during the first 14 days, but thereafter the anticyclone remained unbroken to the coast by intruding depressions. In Asiatic waters conditions were less stable, several HIGH and LOWS succeeding each other, coming from the continent.

The following table gives barometric data for several island and coast stations in west longitudes, including Point Barrow on the Arctic Ocean.

TABLE 1.—*Averages, departures and extremes of atmospheric pressure at sea level at indicated hours, North Pacific Ocean and adjacent waters, February, 1931*

Stations	Average pressure	Departure from normal	Highest	Date	Date	Date
	Inches	*Inch*	*Inches*		*Inches*	
Point Barrow [1] [3]	30.08	−0.04	30.56	7th	29.74	1st.
Dutch Harbor [1]	29.36	−0.24	30.20	22d	28.48	14th.
St. Paul [1]	29.48	−0.17	29.98	22d	28.76	9th.
Kodiak [1]	29.23	−0.39	29.78	23d	28.44	11th.
Midway Island [1]	30.10	+0.11	30.28	24th	29.76	1st.
Honolulu [2]	30.13	+0.03	30.23	14th	29.99	2d.
Juneau [3]	29.69	−0.23	30.29	2d	29.10	18th.
Tatoosh Island [3] [4]	30.00	+0.02	30.48	23d	29.37	16th.
San Francisco [3] [4]	30.01	−0.06	30.27	18th	29.56	12th.
San Diego [3] [4]	29.96	−0.08	30.22	18th	29.56	12th.

[1] P. m. observations only.
[2] For 27 days.
[3] A. m. and p. m. observations.
[4] Corrected to 24-hour mean.

Cyclones and gales.—Conditions of wind and weather on the Pacific were far less intense than in January, and general storm activity was less widespread. Of the traveling cyclones from Asiatic waters, none was of great importance. A moderatly deep storm caused a northwesterly gale of force 11 southeast of the Kurils on the 3d, and fresh to strong gales were noted on a few days east of Japan in connection with some rather shallow and brief-lived disturbances.

In upper waters south and southeast of the Aleutians gales of force 8 to 10 occurred on about 20 days, irregularly distributed, and many of them purely local in character. They were most frequent along that part of the northern routes lying southwest of the Gulf of Alaska, in the region most frequented this month by the Aleutian disturbance. However, the heaviest winds, westerly gales of force 11, in northern waters occurred south of the central Aleutians, one on the 8th, at which time the cyclone was of considerable depth, and the other on the 23d, with the barometer only moderately depressed.

During the early half of February two cyclones, separated from the lower extensions of the Aleutian cyclone, developed, though to no great depth, to the westward of California. The former gathered on the 1st and entered the coast on the 5th. The latter was disconnected from the upper disturbance on the 7th and was reunited with it on the 13th or 14th. Its highest reported winds were of force 8. The earlier was the severer, as may be indicated particularly by the report of the Swedish motor ship *Laurel*, which encountered northerly gales on the 1st, near 25° N., 140° W., and continued in them until near San Francisco on the 6th. On the 3d the maximum wind had increased to a whole gale, and on the 4th, near 32° N., 132° W., to force 11, thus showing the cyclone to have been rather intense, at least in some localities.

Two severe northers were experienced in the Gulf of Tehuantepec. One on the 4th developed full storm force. During the afternoon of the 25th, and continuing through the night, the motor ship *William Penn*, entering the gulf, encountered fresh to whole northerly gales, with squalls of hurricane force and such "short, vicious seas," that at times she "was literally under water."

The prevailing wind direction at Honolulu was from the east, with a maximum velocity of 29 miles an hour from the same direction on the 24th.

Fog.—Fog was more scattered and infrequent that it had been before for many months. At the most, it was reported at some distance off the California coast on four days, and off the coast of Washington and in the vicinity of Midway Island on three days.

BUCKET OBSERVATIONS OF SEA-SURFACE TEMPERATURES

By GILES SLOCUM

STRAITS OF FLORIDA AND CARIBBEAN SEA

The temperatures herein published are the means of the average temperatures for the four quarters of the month, except that, in the case of the 5° subdivisions of the Caribbean Sea, the figures shown are the simple means of the observed temperatures with the entire month taken as a unit. Table 1 shows the lengths of the quarters for each length of month.

Table 2 shows the mean temperature for the Caribbean Sea and the Straits of Florida for February of each year from 1919 to 1930, inclusive, and Table 3 summarizes the temperature for the month in the same areas, including the departures of the February, 1930, means from the 11-year means for February (1920–1930), and the changes from the temperatures for the preceding month of January, 1930.

The means for 1919 are not used in the computations for comparisons, the poor distribution and the dearth of data for that year making them somewhat unreliable.

The chart shows the number of observations taken during the month of February, 1930, within each 1° square; the mean temperature of the Straits of Florida, and of each 5° [1] subdivision of the Caribbean Sea; the 11-year means (1920–1930) for these areas; and the local mean time corresponding to Greenwich mean noon, at which time the mariners are instructed to make the temperature readings.

TABLE 1.—*Lengths of "Quarter-months" used in computing mean sea-surface temperatures*

Length of month	Days of month included in quarter			
	I	II	III	IV
28 days	1–7	8–14	15–21	22–28
29 days	1–7	8–14	15–21	22–29
30 days	1–7	8–15	16–22	23–30
31 days	1–7	8–15	16–23	24–31

[1] In three cases, indicated on the chart, the observations from small, little traveled, and unimportant areas at the outer limits of the Caribbean Sea have been treated as parts of contiguous 5° subdivisions.

TABLE 2.—*Mean sea-surface temperatures in the Caribbean Sea and the Straits of Florida for February, 1919–1930*

Year	Caribbean Sea		Straits of Florida	
	Number of observations	Mean temperature	Number of observations	Mean temperature
1919[1]	31	79.4	14	[1]74.8
1920	114	78.6	22	74.2
1921	167	78.0	42	74.6
1922	187	78.4	82	74.6
1923	281	77.3	68	73.4
1924	369	78.5	102	73.6
1925	213	78.1	72	75.0
1926	350	79.2	115	73.2
1927	285	79.0	106	76.1
1928	407	79.0	125	74.0
1929	387	78.8	130	75.1
1930	481	78.4	145	74.6
Mean (1920-1930)		78.5		74.6

[1] Not used in computations because of insufficient data.

TABLE 3.—*Mean sea-surface temperatures (° F.), and number of observations, February, 1930*

Quarter	Period	Caribbean Sea				Straits of Florida			
		Number of observations	Mean	Departure from 11-year mean (1920-1930)	Change from preceding month	Number of observations	Mean	Departure from 11-year mean (1920-1930)	Change from preceding month
			° F.	° F.	° F.		° F.	° F.	° F.
I	1 to 7	112	78.8			37	74.8		
II	8 to 14	93	78.1			32	74.0		
III	15 to 21	126	78.4			37	75.3		
IV	22 to 28	150	78.5			39	74.5		
Month		481	78.4	−0.1	−0.3	145	74.6	0.0	−1.0

CLIMATOLOGICAL TABLES

CONDENSED CLIMATOLOGICAL SUMMARY

In the following table are given for the various sections of the climatological service of the Weather Bureau the monthly average temperature and total rainfall; the stations reporting the highest and lowest temperatures, with dates of occurrence; the stations reporting the greatest and least total precipitation; and other data as indicated by the several headings.

The mean temperature for each section, the highest and lowest temperatures, the average precipitation, and the greatest and least monthly amounts are found by using all trustworthy records available.

The mean departures from normal temperatures and precipitation are based only on records from stations that have 10 or more years of observations. Of course, the number of such records is smaller than the total number of stations.

Condensed climatological summary of temperature and precipitation by sections, February, 1931

(For description of tables and charts, see REVIEW, January, p. 50)

Section	Temperature								Precipitation					
	Section average	Departure from the normal	Monthly extremes						Section average	Departure from the normal	Greatest monthly		Least monthly	
			Station	Highest	Date	Station	Lowest	Date			Station	Amount	Station	Amount
	°F.	°F.		°F.			°F.		In.	In.		In.		In.
Alabama	49.8	+1.2	2 stations	77	[1]7	2 stations	18	[1]10	3.41	−1.90	River Falls	5.42	Birmingham	1.68
Arizona	48.6	+0.8	Gila Bend	86	[1]1	Alpine	−1	17	3.75	+2.58	Natural Bridge	8.19	Springerville	0.52
Arkansas	48.2	+4.9	Hope	75	[1]3	Dutton	14	10	4.77	+1.47	Dutton	8.04	Junction	2.50
California	48.9	+1.7	Blythe	84	3	Twin Lakes	−10	16	2.56	−1.88	Mount Wilson	6.82	Bishop Creek	0.21
Colorado	32.5	+4.8	2 stations	70	[1]3	2 stations	−16	17	1.26	+0.26	La Veta Pass	6.15	Gunnison	0.00
Florida	58.9	−1.4	Belle Glade	84	18	do	24	11	2.11	−1.00	Apalachicola	5.75	Pelatka	0.40
Georgia	49.8	+1.3	Waycross	79	18	Clayton	13	11	2.83	−2.15	Cornelia	4.47	Meldrim	1.43
Idaho	28.3	+0.2	Glenns Ferry	74	15	Felt	−18	[1]8	1.09	−0.69	Roland	4.30	Grand View	T.
Illinois	37.9	+8.5	Carbondale	72	7	Marengo	1	10	1.29	−0.64	Cairo	3.38	Geneseo	0.12
Indiana	37.6	+7.4	Rome	68	7	Plymouth	10	10	1.65	−0.87	Rome	3.31	Whiting	0.24
Iowa	35.4	+12.8	3 stations	65	[1]2	2 stations	−4	10	0.25	−0.96	Keokuk (No. 2)	1.13	14 stations	T.
Kansas	41.7	+7.9	Atwood	76	19	Centralia	6	10	0.98	−0.03	Overbrook (near)	2.88	Coldwater	0.13
Kentucky	41.6	+5.0	2 stations	72	7	Beattyville	12	15	3.20	−0.25	Franklin	5.49	Whitesburg	1.51
Louisiana	55.8	+2.3	Morgan City	80	7	2 stations	20	11	3.73	−0.84	Logansport	6.36	Tallulah	2.12
Maryland-Delaware	36.6	+2.6	Princess Anne, Md.	65	9	Oakland, Md	7	13	1.66	−1.42	Sines, Md	3.31	Great Falls, Md	1.21
Michigan	28.9	+8.9	Morenci	61	28	3 stations	−21	10	0.79	−0.90	Houghton	2.23	Secord	0.12
Minnesota	27.4	+15.4	2 stations	63	24	2 stations	−26	[1]12	0.40	−0.32	Little Falls	1.85	Redby	T.
Mississippi	51.8	+2.6	Port Gibson	78	8	do	19	11	3.65	−1.21	Clarksdale	7.07	Brookhaven	2.22
Missouri	40.9	+8.5	Doniphan	75	3	do	5	10	2.40	+0.29	Campbell	5.07	Lucerne	0.50
Montana	31.7	+10.5	Ballantine	64	2	Hebgen Dam	−20	8	0.36	−0.36	Heron	3.25	3 stations	0.00
Nebraska	36.7	+11.1	McCook	74	19	2 stations	3	[1]9	0.64	−0.08	Orleans	2.10	2 stations	T.
Nevada	37.9	+2.8	Logandale	76	28	Owyhee	−4	22	0.73	−0.25	Las Vegas	2.71	Beowawe	0.07
New England	24.0	+1.4	Bridgeport, Conn	56	28	Van Buren, Me	−32	2	2.14	−1.05	Rockport, Mass	4.96	Bethlehem, N. H.	0.42
New Jersey	33.3	+3.9	Flemington	62	28	Sussex	−9	11	2.18	−1.45	Chatham	3.42	Cape May City	0.81
New Mexico	38.5	+1.1	Artesia	74	5	Elizabethtown	−13	23	1.49	+0.83	Cloverdale	5.80	Gallegos (near)	0.07
New York	25.1	+3.0	Flushing	58	28	Indian Lake	−28	3	1.80	−0.99	High Market	3.37	Lockport	0.67
North Carolina	44.1	+1.5	Nashville	78	[1]8	Mount Mitchell	4	15	1.83	−2.29	Rock House	6.00	2 stations	0.70
North Dakota	28.0	+17.8	Berthold Agency	62	19	Towner	−31	9	0.28	−0.21	Fullerton	1.62	5 stations	0.00
Ohio	35.2	+5.7	5 stations	65	28	Canfield	4	11	1.85	−0.50	Gallipolis	3.24	Wauseon	1.17
Oklahoma	47.8	+6.5	Eufaula	79	2	Bartlesville	16	10	2.44	+1.27	Tuskahoma	7.51	Boise City	0.50
Oregon	36.5	+0.7	Marshfield	72	12	Seneca	−5	7	1.71	−1.36	Valsetz	9.75	Umatilla	0.02
Pennsylvania	31.9	+3.8	3 stations	66	28	Hawley	−16	11	1.98	−0.99	Elk Lick	3.61	Erie	0.87
South Carolina	47.7	+0.2	2 stations	77	18	Caesars Head	15	11	1.77	−2.51	Walhalla	4.63	Society Hill	0.53
South Dakota	33.7	+14.1	Gannvalley	69	15	McLaughlin	−14	13	0.32	−0.31	2 stations	0.90	2 stations	T.
Tennessee	44.3	+3.3	Clarksville	73	7	Rugby	10	15	4.08	−0.26	Perryville	8.11	Elizabethton	1.30
Texas	53.4	+2.4	Riogrande	86	22	3 stations	21	[1]9	2.98	+1.17	Bon Wier	8.15	Clint	0.27
Utah	33.1	+2.9	St. George	69	[1]25	Lewiston	−2	1	0.71	−0.57	Silver Lake	1.98	Wendover	0.00
Virginia	40.2	+2.9	Diamond Springs	74	9	Burkes Garden	8	11	1.89	−1.20	Emporia	3.59	Rocky Mount	0.81
Washington	36.9	+1.9	2 stations	68	18	Stockdill Ranch	0	7	3.23	−0.87	Big Four	15.75	Wapato	0.03
West Virginia	35.8	+3.6	do	68	[1]7	Bayard	5	3	2.57	−0.56	Pickens	4.68	Wardensville	1.08
Wisconsin	28.9	+12.2	Downing	62	21	2 stations	−25	10	0.61	−0.57	Wausau	1.30	Cuba	0.16
Wyoming	28.1	+5.6	Torrington	67	19	Riverside	−24	22	0.48	−0.31	Bechler River	2.18	Deaver	0.02
Alaska (January)	12.7	+10.4	Mile Seven (Cordova).	59	[1]21	Eagle	−57	22	2.55	+0.50	Mile Seven (Cordova).	20.36	McKinley Park	0.00
Hawaii	69.4	+0.7	Mahukoma	89	99	Volcano Observatory.	47	[1]2	4.14	−2.25	Wahiawa Water Co. Intake	17.60	6 stations	0.00
Porto Rico	73.7	+0.3	Mayaguez	93	3	Guineo Reservoir	49	20	5.98	+3.06	Toro Negro	16.82	Penuelas	0.00

[1] Other dates also.

TABLE 1.—*Climatological data for Weather Bureau stations, February, 1931*

District and station	Elevation of instruments: Barometer above sea level	Elevation of instruments: Thermometer above ground	Elevation of instruments: Anemometer above ground	Pressure: Station, reduced to mean of 24 hours	Pressure: Sea level, reduced to mean of 24 hours	Pressure: Departure from normal	Temperature of the air: Mean max. + mean min. ÷ 2	Temperature of the air: Departure from normal	Temperature of the air: Maximum	Temperature of the air: Date	Temperature of the air: Mean maximum	Temperature of the air: Minimum	Temperature of the air: Date	Temperature of the air: Mean minimum	Temperature of the air: Greatest daily range	Mean wet thermometer	Mean temperature of the dew-point	Mean relative humidity	Precipitation: Total	Precipitation: Departure from normal	Precipitation: Days with .01, or more	Wind: Total movement	Wind: Prevailing direction	Wind: Maximum velocity: Miles per hour	Wind: Maximum velocity: Direction	Wind: Maximum velocity: Date	Clear days	Partly cloudy days	Cloudy days	Average cloudiness, tenth	Total snowfall	Snow, sleet, and ice on ground at end of month
	Ft.	*Ft.*	*Ft.*	*In.*	*In.*	*In.*	°F.	°F.	°F.		°F.	°F.		°F.	°F.	°F.	°F.	%	*In.*	*In.*		*Miles*								*0–10*	*In.*	*In.*
New England							**27.1**	**+1.7**										**74**	**2.23**	**−1.0**										**5.7**		
Eastport	76	67	85	29.85	29.94	−0.04	24.2	+2.7	42	14	30	−1	1	18	31	23	18	76	2.25	−1.1	11	7,939	nw.	31	ne.	19	6	4	18	7.4	11.7	0.3
Greenville, Me	1,070	6		28.72	29.98		18.0		42	26	27	−16	3	9	44				1.84		12	5,242	n.	22			15	10	5	13		19.0	
Portland, Me	103	82	117	29.87	30.00	−.02	26.1	+2.3	47	28	33	3	3	19	28	23	16	67	3.15	−0.8	10	5,509	n.	26	s.	13	11	5	12	5.5	20.9	4.1
Concord	289	70	79	29.66	29.99	−.05	25.1	+2.3	47	26	34	−16	3	16	51				1.29	−1.6	8	3,852	nw.	22	nw.	27	12	6	10	5.0	12.2	3.0
Burlington	403	11	48	29.57	30.04	+.01	18.6	−0.8	41	13	28	−15	3	9	39				1.94	+0.4	14	5,472	s.	33	s.	8	6	7	15	7.0	21.4	19.0
Northfield	876	12	60	29.04	30.04	.00	17.7	+1.3	43	26	30	−22	3	5	55	15	13	85	0.64	−1.6	9	3,810	n.	25	s.	13	6	11	11	6.2	5.5	15.2
Boston	125	106	165	29.84	29.98	−.06	30.6	+1.8	49	13	38	4	1	23	31	27	21	68	4.21	+0.8	9	5,716	nw.	24	nw.	27	10	6	12	5.6	14.0	0.0
Nantucket	12	14	90	29.93	29.94	−.10	33.2	+2.5	49	17	39	10	1	28	27	31	28	82	3.30	−0.1	10	9,267	nw.	37	ne.	20	13	5	10	5.5	5.7	0.0
Block Island	26	11	46	29.94	29.97	−.09	31.7	+1.3	46	14	37	12	1	26	27	29	26	77	2.10	−1.6	10	11,674	w.	48	w.	14	11	6	11	5.4	2.1	0.0
Providence	160	215	251	29.80	29.98	−.07	30.4	+1.4	49	17	38	4	1	23	31	27	21	71	1.98	−1.7	8	7,942	nw.	38	nw.	27	11	4	13	5.3	4.6	T.
Hartford	159	122		29.83	30.02	−.04	29.0	+1.8	49	13	37	2	3	21	30				1.65	−2.2	11		nw.				12	5	11	5.0	6.1	0.0
New Haven	106	74	153	29.89	30.02	−.05	31.0	+2.0	50	28	38	9	1	24	26	27	22	70	2.04	−2.0	9	6,325	nw.	26	ne.	18	14	6	8	4.5	6.0	0.0
Middle Atlantic States							**36.3**	**+2.9**										**70**	**1.76**	**−1.4**										**5.3**		
Albany	97	107	115	29.94	30.05	−.02	25.8	+1.7	46	28	34	−9	3	17	36	23	17	71	2.07	−0.4	9	4,382	s.	21	sw.	27	11	7	10	5.2	6.1	2.0
Binghamton	871	10	84	29.09	30.05	−.03	25.6	+1.6	48	17	35	−12	3	17	48				1.97	−0.3	11	3,663	nw.	20	sw.	13	7	5	16	7.2	9.2	0.1
New York	314	414	454	29.67	30.03	−.05	34.1	+2.8	55	28	42	12	11	26	32	29	22	64	2.44	−1.4	10	10,844	nw.	45	nw.	14	9	9	10	5.5	3.8	0.0
Bellefonte	1,050	5	36	28.90	30.05		30.0		54	28	39	−14	11	21	46	26	24	82	1.59		9		sw.				9	6	13	6.2	8.8	0.0
Harrisburg	374	94	104	29.66	30.08	−.01	35.0	+4.8	55	28	42	15	11	28	29	30	23	63	1.44	−1.5	10	4,140	nw.	25	nw.	14	14	2	12	5.2	2.8	0.0
Philadelphia	114	123	367	29.93	30.06	−.04	37.4	+3.5	55	28	44	18	11	30	25	31	23	60	1.92	−1.4	8	8,843	nw.	34	nw.	14	10	7	11	5.3	1.1	0.0
Reading	325	81	96	29.70	30.06		35.4	+6.6	55	28	43	15	11	28	28	30	25	69	1.90	−1.5	9	4,098	n.	23	nw.	14	13	4	11	5.0	1.6	0.0
Scranton	805	111	119	29.16	30.06	−.02	29.4	+2.1	52	28	38	2	3	21	37	26	21	75	1.45	−1.6	10	4,066	n.	22	nw.	14	7	9	12	6.3	11.8	T.
Atlantic City	52	37	172	29.98	30.04	−.07	36.5	+2.9	55	26	44	16	11	29	27	32	27	72	1.12	−2.2	7	9,945	nw.	40	se.	17	12	7	9	4.8	T.	0.0
Cape May	17	13	49				36.4	+2.3	52	26	44	19	3	29	22	33	30	82	0.81	−2.5	7		nw.				11	5	12		T.	0.0
Sandy Hook	22	10	55	29.99	30.01		34.2		52	28	40	16	11	28	29	30	26	76	1.85	−1.9	9	10,068	nw.	40	nw.	14	13	7	8	4.5	3.7	0.0
Trenton	190	159	183	29.83	30.04		34.4	+3.7	55	28	43	13	11	26	28	30	23	67	2.08	−1.2	7	6,741	n.	32	nw.	14	12	5	11	5.2	1.1	0.0
Baltimore	123	100	215	29.92	30.05	−.06	39.6	+4.2	58	13	47	21	3	32	30	33	26	63	1.41	−2.0	9	6,088	nw.	30	nw.	14	11	5	12	5.2	0.7	0.0
Washington	112	62	85	29.94	30.07	−.04	39.4	+4.1	60	28	47	21	11	31	31	33	25	61	1.36	−1.9	8	4,016	nw.	23	nw.	14	12	4	12	5.3	T.	0.0
Cape Henry	18	8	54	30.03	30.05		41.4	+0.2	72	9	49	27	15	34	36	37	32	75	2.32	−0.9	8	7,302	n.	40	n.	14	11	7	10	5.0	T.	0.0
Lynchburg	681	153	188	29.31	30.07	−.04	42.0	+1.7	62	26	53	22	15	31	34	36	30	67	1.61	−1.3	9	3,909	w.	27	n.	14	10	9	9	4.7	0.9	0.0
Norfolk	91	170	205	29.97	30.07	−.04	43.8	+1.1	69	9	52	24	15	36	34	37	30	67	1.70	−1.5	8	7,188	n.	36	sw.	9	10	7	11	5.1	T.	0.0
Richmond	144	11	52	29.92	30.08	−.03	41.5	+1.9	63	4	52	20	15	31	36	35	30	73	2.60	−0.6	8	4,203	ne.	29	w.	13	12	7	9	4.8	T.	0.0
Wytheville	2,304	49	55	27.63	30.07	−.05	38.8	+3.7	58	24	49	15	15	29	30	32	27	70	1.48	−1.5	9	3,569	w.	19	w.	12	9	8	11	5.4	1.9	0.0
South Atlantic States							**49.0**	**+1.1**										**70**	**1.90**	**−1.8**										**4.9**		
Asheville	2,253	89	104	27.68	30.10	−.03	41.7	+3.2	63	22	53	17	15	30	38	34	29	70	1.24	−1.9	9	4,733	nw.	28	nw.	9	10	9	9	5.2	T.	0.0
Charlotte	779	55	62	29.22	30.07	−.05	46.2	+2.3	67	18	56	24	15	36	32	39	31	62	1.93	−2.2	8	3,248	ne.	16	nw.	14	12	4	12	5.1	T.	0.0
Greensboro	886	5	56	29.10	30.08		41.5		63	18	54	20	15	29	40	35	30	75	1.77		7	4,355	sw.	27	sw.	13	9	11	8	5.1	0.0	0.0
Hatteras	11	5	50	30.04	30.05	−.06	46.9	−0.5	71	9	54	31	15	40	30	43	39	77	2.34	−1.7	8	8,606	ne.	37	n.	14	11	11	6	4.2	T.	0.0
Raleigh	376	103	146	29.66	30.07	−.04	46.0	+2.8	70	18	57	23	15	35	31	38	31	63	1.80	−2.1	7	5,016	sw.	28	sw.	9	10	11	7	4.9	0.0	0.0
Wilmington	78	81	91	30.00	30.09	−.03	49.4	+1.5	73	18	60	26	15	39	32	42	38	73	1.72	−1.5	7	3,921	n.	24	n.	10	9	13	6	4.5	0.0	0.0
Charleston	48	11	92	30.02	30.07	−.05	51.8	−0.6	74	18	60	32	15	43	25	46	41	74	1.67	−1.3	6	5,812	sw.	31	n.	14	10	6	12	5.4	0.0	0.0
Columbia, S. C	351	41	57	29.69	30.08	−.03	49.4	+1.2	70	8	60	28	11	38	34	42	36	65	1.25	−2.5	9	3,877	ne.	27	sw.	9	14	4	10	4.6	0.0	0.0
Due West	711	10	55	29.31	30.10		46.4		66	6	57	24	15	35	37				1.98		8	4,837	sw.	25	w.	9	9	6	9	4.6	0.0	0.0
Greenville, S. C	1,039	139	146	28.94	30.05		46.8	+3.5	66	18	56	26	11	38	29	40	33	64	3.80	−1.4	8	4,977	ne.	29	n.	14	13	5	10	4.7	T.	0.0
Augusta	182	62	77	29.86	30.06	−.06	49.8	−0.1	71	17	62	30	15	38	37	44	42	81	1.87	−2.2	9	2,628	nw.	17	w.	9	12	7	9	4.5	0.0	0.0
Savannah	65	150	194	29.98	30.06	−.06	54.7	+0.7	75	18	64	33	11	45	28	46	41	70	1.82	−1.3	6	6,600	s.	35	nw.	20	11	7	10	5.1	0.0	0.0
Jacksonville	43	209	245	30.01	30.06	−.06	56.4	−1.6	74	17	64	34	11	49	22	49	44	69	1.49	−1.5	7	6,290	n.	33	nw.	20	10	6	12	5.4	0.0	0.0
Florida Peninsula							**64.7**	**−1.8**										**77**	**2.55**	**+0.7**										**5.8**		
Key West	22	10	64	30.00	30.02	−.05	67.5	−3.0	81	28	73	55	11	62	15	62	59	80	3.89	+2.6	6	6,817	n.	28	nw.	4	9	14	5	4.8	0.0	0.0
Miami	25	124	168	30.01	30.04	−.07	65.5	−1.6	78	14	72	47	5	59	25	59	55	74	2.12	+0.3	9	6,749	se.	34	s.	17	3	10	18	7.0	0.0	0.0
Tampa	35	79	197	30.01	30.05	−.05	61.0	−0.9	77	13	70	39	11	52	25	54	50	76	1.65	−0.9	7	6,807	nw.	46	s.	17	11	5	12	5.4	0.0	0.0
Titusville	44	5		30.02	30.07		59.5		78	17	69	39	11	50	33				0.87		6		nw.				10	13	5	5.2	0.0	0.0
East Gulf States							**52.4**	**+1.1**										**71**	**2.92**	**−1.9**										**4.6**		
Atlanta	1,173	190	216	28.80	30.06	−.06	47.6	+2.3	67	6	56	25	11	39	30	41	33	64	2.40	−2.4	10	5,458	nw.	33	nw.	9	13	4	11	4.9	0.0	0.0
Macon	370	78	87	29.67	30.07	−.05	49.8	+0.5	72	17	62	25	11	38	39	42	36	67	2.23	−2.2	9	3,333	nw.	20	nw.	9	13	6	9	4.5	0.0	0.0
Thomasville	273	49	103	29.76	30.07	−.05	54.6	−0.4	75	17	65	30	11	44	30	46	41	72	2.68	−1.8	7	4,529	nw.	24	nw.	14	9	9	10	5.4	0.0	0.0
Apalachicola	36	11	51	30.02	30.06		55.3		72	17	62	34	11	48	23	51	48	82	5.75	+1.8	7	5,280	n.	29	se.	16	12	5	11	4.7	0.0	0.0
Pensacola	56	149	185	30.01	30.07	−.04	54.9	−0.3	68	4	61	34	15	48	22	50	47	79	2.75	−1.6	8	7,631	n.	29	se.	16	12	7	9	4.4	0.0	0.0
Anniston	741	9	57	29.29	30.10	−.02	47.6	+1.8	69	6	59	20	11	36	36				2.81	−2.6	8	2,916	nw.	17	nw.	9	13	4	11	4.7	0.0	0.0
Birmingham	700	11	48	29.30	30.08	−.04	49.7	+1.7	69	6	60	24	11	40	32	42	36	68	1.68	−3.4	11	4,177	n.	24	se.	16	13	4	11	4.7	0.0	0.0
Mobile	57	125	161	30.00	30.06	−.05	55.4	+0.7	74	28	64	33	11	46	27	49	45	76	2.71	−2.6	9	5,711	n.	28	n.	14	13	9	6	4.2	0.0	0.0
Montgomery	223	100	112	29.83	30.08	−.04	52.6	+1.0	74	7	62	28	11	43	31	45	38	64	3.35	−2.1	8	3,608	n.	24	n.	14	14	5	9	4.4	0.0	0.0
Corinth	469	6					48.0		75	6	59	22	11	37	39				3.28		8		nw.				8	10	10		0.0	0.0
Meridian	375	87	95	29.67	30.07	−.04	51.0	+1.4	73	7	62	24	11	40	36	44	39	72	2.47	−3.0	8	3,341	n.	23	sw.	13	14	3	11	4.5	0.0	0.0
Vicksburg	247	65	73	29.80	30.09	−.01	53.8	+2.0	73	7	63	31	11	44	27	46	39	65	2.45	−2.3	9	4,255	n.	21	se.	22	14	6	8	4.4	0.0	0.0
New Orleans	53	76	84	30.00	30.06	−.03	59.0	+1.7	78	17	67	37	11	51	24	53	48	74	3.79	−0.5	7	4,111	ne.	18	n.	14	13	7	8	4.2	0.0	0.0
West Gulf States							**55.2**	**+3.7**										**77**	**3.80**	**+1.3**										**5.6**		
Shreveport	249	77	93	29.79	30.06	−.03	53.8	+2.9	72	4	62	34	15	45	26	49	46	79	3.32	0.0	12	3,516	se.	16	nw.	13	12	6	10	5.1	0.0	0.0
Bentonville	1,303	11	44	28.67	30.06	−.04	45.4	+6.9	66	2	55	20	10	36	31				3.52		12	3,275	s.	19	s.	6	16	2	10		0.0	0.0
Fort Smith	457	79	94	29.56	30.05	−.05	49.1	+6.3	70	5	57	28	10	41	31	44	39	75	5.97	+3.4	9	4,401	e.	20	e.	21	11	4	13	5.6	0.0	0.0
Little Rock	357	136	153	29.69	30.08	−.03	49.6	+4.7	69	3	58	29	15	41	27	43	37	66	4.09	+0.2	9	4,969	n.	31	n.	8	14	1	13	5.1	0.0	0.0
Austin	605	136	148	29.39	30.03		56.8	+3.4	76	19	66	36	10	48	35	51	48	77	5.63	+3.3	12	4,985	se.	28	n.	13	8	10	10	5.6	0.0	0.0
Brownsville	57	83	100	29.96	30.02		63.7	+1.1	79	8	70	50	4	57	25	59	57	85	0.81	−0.4	7	5,819	se.	26	se.	21	3	12	13	7.2	0.0	0.0
Corpus Christi	20	11	78	30.01	30.03	−.02	61.6	+3.2	80	28	68	48	14	55	30	57	55	81	1.74	+0.3	8	6,309	se.	34	nw.	15	6	8	14	6.4	0.0	0.0
Dallas	512	220	227	29.49	30.05		52.1		70	20	60	33	14	44	29				2.36	+0.1	12	7,015	se.	43	sw.	22	14	5	9	4.2	0.0	0.0
Fort Worth	670	106	114	29.31	30.03	−.04	53.6	+5.3	72	20	62	34	14	46	30	48	44	74	2.94	+1.1	13	4,546	se.	30	se.	21	8	7	13	6.0	0.0	0.0
Galveston	54	106	114	30.02	30.08	+.01	58.8	+2.5	73	17	64	45	15	54	17	55	52	84	4.23	+1.4	7	6,439	se.	27	n.	9	11	4	13	5.6	0.0	0.0
Groesbeck	461	11	56	29.55	30.04		53.9		72	20	62	36	10	46	28				5.06	+2.2	10	5,276	n.	27	se.	15	8	8	12	6.0	0.0	0.0
Houston	138	292	314	29.91	30.06		58.4	+2.5	74	20	66	40	10	51	23				4.76	+1.6	10	7,557	se.	44	e.	16	10	5	13	5.9	0.0	0.0
Palestine	510	64	72	29.52	30.08	−.02	54.4	+3.2	72	20	63	38	10	46	27	49	45	76	4.69	+1.6	10	4,644	s.	21	nw.	22	10	5	13	5.5	0.0	0.0
Port Arthur	24	58	66	30.02	30.06		58.4		76	17	65	39	10	51	22				4.96	+1.4	7	4,685	n.	28	e.	16	10	4	14	5.9	0.0	0.0
San Antonio	693	242	301	29.29	30.02	−.03	57.4	+2.0	75	17	66	40	10	49	28	52	47	73	2.68	+1.0	9	7,240	n.	36	ne.	15	10	10	8	5.3	0.0	0.0
Taylor	571	38	51	29.46	30.06	.00	55.6	+4.3	74	19	63	35	10	47	34				3.87	+1.8	10	4,387	s.	24	se.	15	9	10	9	5.2	0.0	0.0

TABLE 1.—*Climatological data for Weather Bureau stations, February, 1931*—Continued

District and station	Elevation of instruments: Barometer above sea level	Elevation of instruments: Thermometer above ground	Elevation of instruments: Anemometer above ground	Pressure: Station, reduced to mean of 24 hours	Pressure: Sea level, reduced to mean of 24 hours	Pressure: Departure from normal	Temperature of the air: Mean max. + mean min. ÷ 2	Temperature of the air: Departure from normal	Temperature of the air: Maximum	Temperature of the air: Date	Temperature of the air: Mean maximum	Temperature of the air: Minimum	Temperature of the air: Date	Temperature of the air: Mean minimum	Temperature of the air: Greatest daily range	Mean wet thermometer	Mean temperature of the dew-point	Mean relative humidity	Precipitation: Total	Precipitation: Departure from normal	Precipitation: Days with .01, or more	Wind: Total movement	Wind: Prevailing direction	Wind: Maximum velocity: Miles per hour	Wind: Maximum velocity: Direction	Wind: Maximum velocity: Date	Clear days	Partly cloudy days	Cloudy days	Average cloudiness, tenths	Total snowfall	Snow, sleet, and ice on ground at end of month
Ohio Valley and Tennessee	*Ft.*	*Ft.*	*Ft.*	*In.*	*In.*	*In.*	°F.	°F.	°F.		°F.	°F.		°F.	°F.	°F.	°F.	%	*In.*	*In.*		*Miles*								*0–10*	*In.*	*In.*
							40.3	+4.3										73	2.78	−0.6										6.1		
Chattanooga	762	190	215	29.25	30.07	−0.06	47.0	+2.9	66	8	56	25	15	38	30	40	33	63	4.78	−0.1	9	4,017	ne.	24	w.	9	12	4	12	5.1	0.0	0.0
Knoxville	995	102	111	29.00	30.08	−.04	44.7	+2.8	66	8	54	21	15	35	31	39	33	70	2.93	−1.6	12	3,200	n.	20	sw.	7	9	4	15	5.7	T.	0.0
Memphis	399	76	97	29.64	30.07	−.04	48.3	+4.0	68	6	56	28	15	40	27	42	37	69	4.85	+0.5	8	5,141	n.	28	n.	8	14	3	11	4.8	0.0	0.0
Nashville	546	168	191	29.51	30.11	−.01	44.3	+2.7	67	6	53	22	15	36	32	39	34	72	5.05	+0.9	10	4,977	nw.	26	nw.	13	11	2	15	5.8	T.	0.0
Lexington	989	193	230	29.03	30.13	+.02	39.3	+3.9	62	7	47	18	15	32	26				3.40	−0.2	9	6,946	n.	30	w.	13	8	4	16	6.2	1.5	0.0
Louisville	525	188	234	29.52	30.11	.00	41.4	+4.2	63	7	49	20	14	34	27	37	32	73	2.88	−0.7	7	5,535	n.	24	n.	13	7	7	14	6.4	1.0	0.0
Evansville	431	76	116	29.63	30.11	.00	41.9	+5.6	66	7	50	19	14	34	28	37	31	71	2.33	−0.9	10	4,879	n.	23	sw.	12	10	5	13	5.6	T.	0.0
Indianapolis	822	194	230	29.18	30.09	−.01	38.0	+6.9	60	3	45	14	14	31	27	34	29	73	1.76	−1.0	9	5,869	sw.	26	sw.	3	10	5	13	5.8	T.	0.0
Royal Center	736	11	55	29.28	30.11	------	35.2	------	57	3	43	14	14	28	30				1.11	−1.2	10	5,573	nw.	26	nw.	13	6	10	12	6.0	0.5	0.0
Terre Haute	575	96	129	29.47	30.10	------	38.9	------	63	3	46	14	14	31	29	35	31	78	2.06	−0.6	11	4,721	nw.	23	n.	3	9	5	14	5.7	0.1	0.0
Cincinnati	627	11	51	29.41	30.11	+.01	38.8	+6.0	63	7	46	19	14	31	30	34	31	77	1.88	−1.1	10	3,824	sw.	19	sw.	7	10	4	14	6.4	1.3	0.0
Columbus	822	216	230	29.19	30.09	.00	36.8	+6.1	60	28	44	16	14	30	27	33	28	73	1.54	−1.1	13	5,686	nw.	28	nw.	13	6	8	14	6.2	1.9	0.0
Dayton	899	137	173	29.12	30.10	------	37.6	+6.2	60	28	44	18	14	31	26	34	30	76	1.77	−0.9	14	4,475	sw.	25	w.	7	6	9	13	6.2	0.4	0.0
Elkins	1,947	59	67	28.00	30.13	+.03	34.2	+2.6	61	28	43	15	11	25	40	30	27	81	3.19	+0.1	13	2,696	nw.	22	nw.	13	6	5	17	7.2	3.7	0.0
Parkersburg	637	77	82	29.44	30.12	+.02	37.8	+3.6	64	28	46	14	11	29	35	33	28	75	2.97	−0.2	11	2,951	nw.	17	nw.	14	8	3	17	6.9	3.0	0.0
Pittsburgh	842	353	410	29.15	30.09	.00	34.6	+2.3	62	28	42	15	14	28	32	31	27	77	1.93	−0.7	11	5,304	sw.	27	nw.	14	6	7	15	6.9	4.1	0.0
Lower Lake Region							29.3	+4.4										79	1.37	−1.0									7.0		
Buffalo	767	247	280	29.19	30.05	−.01	27.1	+2.8	50	28	34	6	1	20	29	25	23	85	1.50	−1.4	12	9,469	sw.	50	w.	15	3	9	16	7.4	10.2	0.3
Canton	448	10	61	29.53	30.04	------	17.9	−0.1	39	13	29	−19	7	7	49				1.15	−1.1	17	5,773	sw.	25	sw.	13	9	7	12	6.2	10.5	13.0
Ithaca	836	74	100	29.11	30.05	------	27.2	+2.7	47	17	35	−1	3	19	34	24	20	80	1.34	−0.6	16	5,859	nw.	27	nw.	14	4	6	18	7.7	14.2	0.4
Oswego	335	71	85	29.67	30.05	−.01	25.8	+1.9	42	17	34	−7	3	18	45	24	21	81	1.67	−1.0	16	6,245	s.	26	n.	2	3	2	23	8.3	13.9	7.7
Rochester	523	86	102	29.47	30.07	+.01	28.2	+3.6	44	28	36	4	3	21	38	26	22	77	1.40	−1.3	15	5,356	sw.	28	w.	14	3	10	15	7.4	6.8	0.8
Syracuse	596	65	79	29.38	30.05	−.02	27.2	+3.4	45	13	35	−5	3	20	44				1.27	−1.4	18	4,470	w.	22	sw.	14	4	5	19	7.6	7.7	1.6
Erie	714	130	166	29.27	30.06	−.01	30.4	+3.5	52	28	37	12	11	24	30	28	25	80	0.87	−1.7	7	6,964	nw.	32	sw.	2	6	6	16	7.1	1.6	0.0
Cleveland	762	267	337	29.23	30.07	.00	33.0	+5.6	58	28	39	13	14	27	31	29	25	76	1.29	−1.2	6	7,647	n.	37	w.	13	6	6	16	7.0	0.5	0.0
Sandusky	629	5	67	29.39	30.09	+.02	33.4	+6.0	53	3	39	16	14	28	28				1.71	−0.4	9	4,891	sw.	27	w.	13	7	4	17	6.8	1.4	0.0
Toledo	628	208	243	29.39	30.10	+.03	34.0	+6.7	59	28	40	14	14	28	29	30	25	73	1.46	−0.6	10	7,000	sw.	30	w.	15	11	5	12	5.7	0.8	0.0
Fort Wayne	856	100	119	29.14	30.09	------	34.6	+8.8	59	28	41	16	14	28	30	31	28	79	1.36	−1.0	12	5,416	nw.	25	nw.	13	6	9	13	6.2	2.2	0.0
Detroit	730	218	258	29.27	30.09	+.03	32.8	+7.5	56	28	39	12	14	27	26	30	26	80	1.40	−0.8	8	6,101	n.	25	sw.	5	10	4	14	6.0	3.5	0.0
Upper Lake Region							28.9	+9.6										82	1.00	−0.8									6.5		
Alpena	609	13	92	29.39	30.08	+.05	26.0	+8.0	44	15	33	1	14	20	27	24	21	81	0.88	−0.8	11	6,333	nw.	29	e.	7	6	5	17	7.1	8.2	T.
Escanaba	612	54	60	29.40	30.09	+.03	26.4	+11.0	45	3	33	6	10	20	24	24	21	83	0.86	−0.6	4	5,710	n.	30	n.	9	8	6	14	6.1	8.6	5.0
Grand Haven	632	54	89	29.38	30.08	+.03	31.6	+7.4	47	27	38	10	10	26	22	30	27	85	0.86	−1.3	10	6,405	sw.	31	n.	3	5	6	17	7.0	5.6	0.0
Grand Rapids	707	70	244	29.30	30.10	+.05	32.2	+8.5	50	25	39	8	10	26	25	29	25	77	0.79	−1.4	10	6,949	sw.	33	sw.	1	7	6	15	6.5	7.2	0.0
Houghton	668	64	99	29.33	30.09	+.04	24.7	+11.0	43	24	33	−5	10	17	37				2.23	+0.4	10	5,260	e.	30	w.	3	4	9	15	7.2	22.0	13.5
Lansing	878	6	88	29.10	30.07	------	30.4	+7.5	49	16	37	9	10	24	30	28	27	91	0.99	−0.9	10	5,270	sw.	24	nw.	13	9	5	14	6.3	7.9	0.0
Ludington	637	60	66	29.36	30.07	------	31.1	+8.6	43	27	36	10	10	26	22	29	27	86	0.67	−1.4	9	5,858	n.	27	sw.	1	8	7	13	6.4	4.2	0.0
Marquette	734	77	111	29.25	30.08	+.03	27.6	+11.3	50	15	34	5	13	21	24	25	21	80	1.51	−0.4	12	5,942	nw.	34	nw.	13	4	9	15	7.3	15.1	8.9
Port Huron	638	70	120	29.35	30.07	+.02	29.6	+6.9	48	16	36	8	14	23	28	27	24	81	1.34	−0.6	10	6,271	nw.	26	nw.	13	6	8	14	6.9	9.1	T.
Sault Ste. Marie	614	11	52	29.37	30.10	+.07	20.8	+8.2	40	15	30	−20	10	11	41	20	18	89	1.31	−0.6	12	3,957	se.	32	nw.	13	7	6	15	6.5	15.7	5.4
Chicago	673	7	131	29.36	30.10	+.02	35.6	+9.3	54	3	41	12	14	30	26	32	28	77	0.76	−1.4	7	6,231	ne.	25	sw.	1	7	10	11	6.1	0.4	0.0
Green Bay	617	109	141	29.38	30.07	+.01	29.0	+11.6	47	25	36	−2	14	22	27	27	23	81	0.64	−0.9	4	6,217	n.	25	nw.	3	5	10	13	6.8	7.1	1.0
Milwaukee	681	125	221	29.33	30.09	+.03	33.4	+10.6	51	16	40	7	14	27	25	30	26	77	0.45	−1.4	5	7,647	n.	31	sw.	1	9	6	13	5.8	3.8	T.
Duluth	1,133	5	47	28.84	30.10	+.02	26.2	+14.8	56	24	35	−5	13	18	34	23	19	80	0.69	−0.4	3	7,316	ne.	36	nw.	13	13	6	9	4.9	9.2	5.0
North Dakota							28.3	+20.4										81	0.42	−0.1									5.2		
Moorhead	940	50	58	29.05	30.11	.00	26.2	+18.1	53	15	35	−12	9	17	37	24	21	84	0.30	−0.4	3	4,986	n.	22	nw.	25	8	8	12	6.0	3.6	T.
Bismarck	1,674	8	57	28.24	30.08	−.04	30.4	+20.1	59	15	40	0	9	21	38	26	22	77	0.74	+0.3	4	4,609	nw.	24	n.	8	12	7	9	4.7	9.9	1.3
Devils Lake	1,478	11	44	28.46	30.09	−.02	25.6	+20.5	51	15	34	−13	9	17	31	23	21	86	0.13	−0.4	3	5,377	s.	23	nw.	8	10	8	10	5.3	1.4	T.
Ellendale	1,457	10	56	28.48	30.09	------	28.0	------	56	15	37	−6	9	19	37				0.74	+0.2	7	7,642	nw.	38	e.	27	7	7	14	6.3	6.4	2.5
Grand Forks	833	12	67				24.4	------	46	15	33	−14	9	16	34	22			0.09	------	2		nw.	35	nw.	9	18	5	5	----	1.0	T.
Williston	1,878	41	48	28.03	30.06	−.05	31.0	+22.9	53	18	41	−2	9	21	37	26	22	76	0.19	−0.2	3	3,826	se.	31	w.	24	13	10	5	3.7	2.3	0.0
Upper Mississippi Valley							36.2	+11.6										76	1.05	−0.6									5.2		
Minneapolis	918	102	208	29.06	30.08	------	32.0	+16.1	57	24	40	0	9	24	34				0.70	−0.2	4	6,098	nw.	26	nw.	3	12	4	12	5.4	7.0	2.0
St. Paul	837	236	261	29.15	30.09	.00	31.4	+15.6	57	24	40	0	10	23	33				0.72	−0.2	4	5,851	nw.	28	w.	7	12	5	11	4.8	7.7	3.5
La Crosse	714	11	48	29.29	30.08	.00	32.5	+13.3	59	24	41	−1	14	24	31	29	25	79	0.71	−0.4	4	2,731	s.	13	nw.	13	11	7	10	5.1	7.5	1.0
Madison	974	70	78	29.01	30.10	+.03	31.4	+12.3	48	24	38	5	14	25	23	28	26	83	0.40	−1.1	6	4,790	nw.	30	n.	28	10	6	12	5.6	3.9	0.0
Wausau	1,247	4	62	------	30.10	------	27.0	------	53	24	36	−10	10	18	38				1.30	+0.1	5	3,354	n.	18	w.	8	8	9	11	----	12.9	3.7
Charles City	1,015	10	51	29.00	30.11	+.01	32.6	+15.5	58	24	41	5	10	24	29	28	25	80	0.61	−0.5	4	3,470	se.	18	sw.	15	14	7	7	4.1	4.3	0.0
Davenport	606	71	79	29.43	30.11	+.01	36.8	+11.9	59	27	45	11	14	29	26	32	28	75	0.14	−1.4	3	5,148	sw.	28	ne.	6	10	9	9	5.3	T.	0.0
Des Moines	861	5	99	29.17	30.11	.00	36.8	+13.1	58	27	47	10	10	27	30	31	26	70	0.09	−1.0	1	5,198	s.	27	e.	6	11	9	8	5.0	T.	0.0
Dubuque	700	81	96	29.33	30.10	+.01	34.3	+12.1	51	24	42	8	14	27	26	31	28	81	0.25	−1.1	3	3,238	s.	18	nw.	13	10	6	12	5.7	1.4	0.0
Keokuk	614	64	78	29.43	30.13	+.02	38.8	+10.5	63	3	47	14	10	30	29	33	28	71	1.08	−0.5	6	3,772	sw.	18	sw.	11	13	4	11	5.0	0.1	0.0
Cairo	358	87	93	29.70	30.10	−.02	43.8	+5.3	70	7	52	23	15	36	30	38	33	72	3.38	+0.2	7	5,460	n.	28	n.	24	10	5	13	5.8	0.0	0.0
Peoria	609	11	45	29.44	30.12	+.02	36.7	+10.8	60	3	45	13	14	29	29	32	29	81	0.83	−1.2	10	3,609	s.	17	e.	6	11	5	12	5.1	T.	0.0
Springfield, Ill	636	5	191	29.41	30.10	.00	38.6	+9.1	64	3	46	15	14	31	26	34	30	77	1.57	−0.8	10	6,542	s.	26	ne.	28	9	8	11	5.7	0.1	0.0
Hannibal	534	74	109	29.52	30.11	.00	39.3	+9.6	66	3	47	16	14	31	32				2.17	+0.3	7	4,228	sw.	23	sw.	11	12	3	13	6.3	1.4	0.0
St. Louis	568	265	303	29.48	30.10	−.01	41.7	+7.2	67	3	50	18	14	34	27	37	31	69	1.77	−0.8	10	6,438	n.	29	sw.	12	11	6	11	5.1	T.	0.0
Missouri Valley							38.6	+12.8										68	1.01	−0.2									4.6		
Columbia, Mo.	784	6	84	29.24	30.10	−.01	40.9	+9.2	67	3	49	17	10	33	34				3.19	+1.2	11	4,241	n.	21	nw.	9	11	5	12	5.6	0.8	0.0
Kansas City	963	161	181	29.04	30.10	−.01	42.2	+11.0	66	2	50	17	10	34	26	36	31	70	1.24	−0.5	5	5,521	s.	24	n.	25	12	8	8	4.7	T.	0.0
St. Joseph	967	11	49	29.03	30.09	------	40.1	------	64	2	49	15	10	31	27	34	28	69	0.81	−0.6	4	4,342	ne.	19	sw.	15	15	6	7	4.0	T.	0.0
Springfield, Mo.	1,324	98	104	28.65	30.08	−.03	43.2	+8.0	63	2	52	18	10	35	25	38	32	69	3.06	+0.7	10	5,893	se.	24	se.	22	15	7	6	3.8	0.0	0.0
Iola	984	11	50	29.01	30.09	−.01	42.7	+9.5	69	3	53	16	10	33	34				1.53	−0.1	6	3,864	n.	22	ne.	8	9	5	14	5.9	0.0	0.0
Topeka	987	92	107	------	------	------	41.2	+10.2	66	2	50	16	10	32	32				1.34	−0.2	5	5,099	se.	25	sw.	15	11	9	8	4.5	T.	0.0
Lincoln	1,189	11	81	28.79	30.10	.00	38.1	+12.0	62	11	49	11	10	27	35	33	26	68	1.09	+0.1	3	4,891	s.	21	n.	28	10	9	9	5.3	0.4	T.
Omaha	1,105	115	122	28.89	30.10	−.01	38.6	+13.1	59	11	47	15	10	30	29	32	25	63	0.03	−0.9	1	4,296	nw.	21	nw.	9	17	5	6	3.6	0.4	0.0
Valentine	2,598	47	54	27.31	30.09	.00	36.1	+14.7	62	15	47	12	9	25	38	30	25	72	0.37	−0.2	5	4,513	w.	34	sw.	26	9	9	10	5.1	0.1	0.0
Sioux City	1,135	94	164	28.86	30.11	−.01	36.4	+15.4	59	24	46	12	13	27	30	31	24	64	0.04	−0.8	1	6,345	nw.	31	se.	26	14	6	8	4.2	T.	0.0
Huron	1,306	59	74	28.67	30.11	−.01	32.6	+18.3	64	15	44	4	13	21	40	27	22	70	0.19	−0.4	5	5,128	s.	25	se.	26	14	5	9	4.2	1.3	0.0
Pierre	1,572	70	75	28.37	30.08	−.03	35.8	+17.2	65	15	47	10	9	25	41	30	24	69	0.13	−0.3	4	4,520	nw.	24	nw.	8	9	11	8	4.8	0.6	0.0
Yankton	1,233	49	57	28.76	30.11	−.01	35.8	+14.9	62	15	46	12	13	25	37				0.11	−0.7	2	4,188	nw.	22	sw.	10	15	4	9	4.2	T.	0.0

TABLE 1.—*Climatological data for Weather Bureau stations, February, 1931*—Continued

District and station	Elevation of instruments: Barometer above sea level	Elevation of instruments: Thermometer above ground	Elevation of instruments: Anemometer above ground	Pressure: Station, reduced to mean of 24 hours	Pressure: Sea level, reduced to mean of 24 hours	Pressure: Departure from normal	Temperature of the air: Mean max. + mean min. ÷ 2	Temperature of the air: Departure from normal	Temperature of the air: Maximum	Temperature of the air: Date	Temperature of the air: Mean maximum	Temperature of the air: Minimum	Temperature of the air: Date	Temperature of the air: Mean minimum	Temperature of the air: Greatest daily range	Mean wet thermometer	Mean temperature of the dew-point	Mean relative humidity	Precipitation: Total	Precipitation: Departure from normal	Precipitation: Days with .01, or more	Wind: Total movement	Wind: Prevailing direction	Wind: Maximum velocity: Miles per hour	Wind: Maximum velocity: Direction	Wind: Maximum velocity: Date	Clear days	Partly cloudy days	Cloudy days	Average cloudiness, tenths	Total snowfall	Snow, sleet, and ice on ground at end of month
	Ft.	*Ft.*	*Ft.*	*In.*	*In.*	*In.*	°F.	°F.	°F.		°F.	°F.		°F.	°F.	°F.	°F.	%	*In.*	*In.*		*Miles*							0–10	*In.*	*In.*
Northern Slope							**32.7**	**+11.0**										**67**	**0.42**	**−0.3**									5.3			
Billings	3,140	5					36.2		62	2	52	8	8	20	49				0.28		7		nw.				11	10	7		1.7	
Havre	2,505	11	67	27.34	30.03	−0.04	35.6	+22.0	57	18	46	14	9	25	38	30	23	65	0.02	−0.5	1	5,397	sw.	30	sw.	18	13	10	5	4.4	T.	0.0
Helena	4,124	89	113	25.79	30.08	−.03	33.3	+10.3	59	18	42	12	8	24	33	27	19	57	0.18	−0.5	2	4,613	sw.	28	sw.	16	6	10	12	5.9	2.3	0.0
Kalispell	2,973	48	56	26.99	30.14	+.06	27.9	+4.6	49	18	34	7	9	21	20	26	23	79	0.27	−0.8	5	2,421	nw.	15	nw.	24	1	9	18	7.8	1.9	0.0
Miles City	2,371	48	55	27.49	30.10	+.01	36.3	+19.5	58	19	47	11	9	26	35	31	25	69	0.47	0.0	4	2,876	s.	21	nw.	24	14	5	9	4.8	1.1	0.0
Rapid City	3,259	50	58	26.60	30.10	+.02	36.3	+12.9	63	14	48	11	9	25	47	30	24	66	0.13	−0.4	3	3,907	n.	22	n.	24	10	7	11	5.6	0.6	0.0
Cheyenne	6,088	84	101	23.95	30.06	+.03	32.2	+4.9	57	19	42	10	13	22	33	27	20	63	0.74	+0.1	6	6,682	w.	33	w.	10	6	11	11	6.2	7.1	3.5
Lander	5,372	60	68	24.61	30.10	+.02	29.3	+6.8	52	18	42	3	13	16	35	25	19	71	0.77	+0.1	4	1,812	sw.	20	nw.	16	15	11	2	3.8	8.4	0.5
Sheridan	3,790	10	47	26.08	30.08		32.2		58	18	46	6	14	18	49	27	19	65	0.59	−0.1	5	2,130	nw.	23	nw.	26	10	10	8	4.8	4.9	T.
Yellowstone Park	6,241	11	48		30.17	+.07	25.2	+5.6	45	4	36	2	18	14	36			71	0.25	−1.1	8	4,108	sw.	21	n.	27	10	9	9		8.1	7.1
North Platte	2,821	11	51	27.07	30.06	−.01	38.6	+12.0	65	19	50	20	14	27	39	32	26	68	0.76	+0.2	3	3,654	w.	18	s.	26	10	12	6	4.8	1.0	0.0
Middle Slope							**42.0**	**+8.2**										**68**	**1.20**	**+0.3**									5.3			
Denver	5,292	106	113	24.69	30.03	+.02	38.8	+6.1	64	19	48	23	28	30	30	31	22	58	1.11	+0.6	7	3,931	s.	24	w.	16	5	16	7	5.4	18.0	6.0
Pueblo	4,685	80	86	25.26	30.01	+.01	38.8	+5.9	63	19	52	16	10	26	42	31	23	59	1.11	+0.6	6	3,200	nw.	23	w.	6	12	8	8	4.7	9.2	5.2
Concordia	1,392	50	58	28.59	30.10	+.01	39.8	+10.0	66	2	50	17	14	29	35	34	29	72	1.46	+0.6	3	4,309	s.	20	se.	21	8	13	7	5.2	T.	0.0
Dodge City	2,509	11	51	27.42	30.06	.00	42.6	+9.4	67	20	54	24	10	31	38	36	30	71	0.56	−0.2	4	5,413	s.	26	se.	21	12	10	6	4.4	1.3	1.3
Wichita	1,358	139	158	28.59	30.05	−.03	43.6	+9.2	64	3	52	18	10	35	28	38	33	71	0.64	−0.6	9	6,701	s.	30	s.	15	9	6	13	5.6	0.0	0.0
Broken Arrow	765	11	56	29.23	30.06		46.6		69	6	56	22	10	37	33				2.05	+0.7	11	7,190	n.	35	ne.	22	9	7	12	5.8	0.0	0.0
Oklahoma City	1,214	10	47	28.74	30.04	−.03	48.3	+8.7	72	6	57	27	14	40	29	42	38	74	1.48	+0.4	12	5,415	s.	22	se.	21	8	8	12	6.3	0.0	0.0
Southern Slope							**49.8**	**+3.8**										**71**	**1.65**	**+0.9**									5.4			
Abilene	1,738	10	52	28.20	30.03	−.02	51.4	+4.2	72	19	60	29	14	43	30	46	42	76	2.54	+1.5	8	5,152	s.	30	s.	21	11	4	13	5.6	0.0	0.0
Amarillo	3,676	10	49	26.23	30.00	−.02	45.0	+6.9	70	5	55	26	28	35	34	38	32	68	1.83	+1.1	8	5,164	sw.	24	se.	20	14	4	10	5.0	4.7	3.5
Del Rio	944	64	71	28.99	29.99	−.01	57.2	+1.2	77	22	66	41	19	48	33	51	47	75	1.04	+0.5	8	4,543	se.	29	se.	15	8	13	7	5.4	0.0	0.0
Roswell	3,566	75	85	26.35	29.99	+.01	45.4	+2.9	70	5	56	27	18	34	37	39	32	65	1.19	+0.6	8	4,385	s.	30	n.	28	8	9	11	5.8	2.1	T.
Southern Plateau							**47.2**	**+2.4**										**67**	**1.35**	**+0.7**									4.8			
El Paso	3,778	152	175	26.15	29.97	+.02	50.0	+1.0	66	5	59	33	24	41	28	42	34	61	0.89	+0.5	8	6,208	e.	35	w.	15	12	12	4	4.5	0.0	0.0
Santa Fe	7,013	38	53	23.18	29.99	+.01	35.6	+2.5	50	7	44	22	28	26	30	25	72	0.73	0.0	11	3,148	n.	17	n.	16	5	10	13	6.3	4.5	0.2
Flagstaff	6,907	10	59	23.25	29.90	−.10	33.8	+3.0	52	3	43	13	24	24	33	30		78	2.10		9	3,493	sw.	23	n.	28	6	10	12		15.5	T.0
Phoenix	1,108	10	107	28.78	29.94	−.05	57.8	+2.7	80	3	68	38	24	48	34	50	42	63	3.71	+2.9	8	2,893	e.	23	nw.	19	8	12	8	5.1	0.0	0.
Yuma	141	9	54	29.80	29.95	−.05	59.4	+0.8	79	3	71	38	23	48	33	51	43	60	1.13	+0.7	6	2,625	ne.	27	nw.	19	15	10	3	3.3	0.0	0.0
Independence	3,957	6	27	25.94	30.00	−.06	46.6	+4.4	66	28	59	24	23	34	34	37			0.31	−0.5	2		nw.				13	4	11		0.0	0.0
Middle Plateau							**37.0**	**+3.6**										**70**	**0.66**	**−0.4**									6.1			
Reno	4,532	74	81	25.44	30.04	−.04	39.5	+3.9	59	18	51	20	20	28	32	34	27	63	0.47	−0.7	4	2,328	w.	27	w.	18	10	11	7	5.1	T.	0.0
Tonopah	6,090	12	20				36.7		55	18	44	16	22	29	22	32	27	70	0.57		5		se.									
Winnemucca	4,344	18	56	25.62	30.07	−.02	37.2	+3.7	58	1	49	15	22	25	37	32	25	66	0.51	−0.4	6	4,403	ne.	24	nw.	19	11	10	7	4.6	T.	0.0
Modena	5,473	10	43	24.58	29.98	−.06	34.9	+3.9	54	18	43	19	23	27	30	31	28	80	0.88	−0.1	8	4,036	e.	24	e.	12	4	9	15	7.0	3.0	0.0
Salt Lake City	4,360	163	203	25.64	30.10	+.02	34.0	+0.2	53	18	39	22	2	29	22	31	27	77	0.61	−0.9	8	2,976	nw.	24	se.	19	6	7	15	7.0	2.0	0.0
Grand Junction	4,602	60	68	25.36	29.96	−.08	39.2	+6.3	57	26	49	23	2	30	31	33	27	65	0.81	+0.2	11	2,652	se.	17	nw.	27	4	8	16	7.0	0.4	0.0
Northern Plateau							**35.3**	**+2.1**										**74**	**0.64**	**−0.7**									6.6			
Baker	3,471	48	53	26.50	30.17	+.05	30.9	+1.9	46	18	40	13	7	22	25	28	25	77	0.51	−0.7	8	3,209	se.	16	se.	18	4	12	12	6.2	3.7	0.0
Boise	2,739	79	87	27.25	30.17	+.05	36.2	+1.4	54	14	45	23	8	28	24	32	27	71	0.84	−0.6	8	2,597	se.	20	nw.	19	8	9	11	5.8	0.1	0.0
Lewiston	757	40	48	29.33	30.16	+.05	39.5	+2.5	56	14	47	23	9	32	29				0.88	−0.4	9	1,604	e.	1	7ne.	17	3	9	16	7.3	T.	0.0
Pocatello	4,477	760	68	25.51	30.16	+.06	29.0	+0.1	47	18	37	9	25	20	33	26	23	78	0.42	−0.8	7	4,104	se.	28	sw.	16	8	10	10	5.6	3.6	0.0
Spokane	1,929	101	110	28.04	30.14	+.05	34.6	+3.3	54	18	41	18	12	28	24	32	28	76	0.76	−1.0	8	2,981	s.	21	s.	18	4	10	14	6.9	2.6	0.0
Walla Walla	991	57	65	29.05	30.14	+.03	39.0	+1.9	61	18	45	25	9	33	22	36	31	76	0.90	−0.9	10	2,661	s.	21	s.	19	3	9	16	7.7	T.	0.0
Yakima	1,076	58	67	28.96	30.13		38.2	+3.7	60	17	47	24	14	30	26	34	27	64	0.15	−0.8	3	2,378	n.	28	s.	18	7	8	13	6.4	0.5	0.0
North Pacific Coast Region							**44.9**	**+3.0**										**75**	**3.44**	**−1.7**									7.1			
North Head	211	11	56	29.82	30.06	.00	46.5	+3.5	59	2	51	37	21	42	14	43	39	76	4.95	−2.5	15	9,722	se.	58	sw.	18	4	8	16	6.9	0.0	0.0
Port Angeles	29	8	53		30.06		42.1		51	18	48	32	6	36	16				3.25	0.0	12	3,551	s.	26	sw.	15	5	10	13		0.0	0.0
Seattle	125	215	250	29.92	30.05	−.01	44.4	+3.3	62	13	50	35	21	39	23	41	36	72	3.25	−0.6	13	5,400	se.	33	sw.	15	5	12	11	6.5	0.0	0.0
Tacoma	194	172	201	29.85	30.06	.00	43.5	+2.9	60	13	50	31	13	37	29				3.38	−1.3	13	4,849	s.	36	sw.	15	4	9	15	6.8	0.0	0.0
Tatoosh Island	86	9	53	29.90	30.00	.00	45.6	+4.6	55	3	48	38	26	43	9	43	40	83	7.41	−2.0	18	11,687	e.	49	s.	17	5	3	20	7.5	0.0	0.0
Medford	1,329	29	58	28.63	30.06		43.8		66	12	56	24	6	31	40	39	34	72	1.06	−1.3	9		s.	26	w.	18	5	11	12	6.8	T.	0.0
Portland, Oreg.	153	68	106	29.92	30.08	.00	45.0	+2.9	58	18	51	32	22	39	19	41	35	70	2.40	−3.0	12	3,560	e.	24	sw.	18	2	8	18	7.8	0.0	0.0
Roseburg	510	75	99	29.52	30.08	−.02	44.5	+1.1	64	28	53	28	24	36	30	42	38	78	1.80	−2.7	14	1,995	nw.	19	s.	25	2	11	15	7.4	0.	0.00
Middle Pacific Coast Region							**53.4**	**+3.5**										**76**	**1.53**	**−2.4**									5.8			
Eureka	62	73	89	30.00	30.07	−.04	49.8	+2.6	62	17	56	37	20	44	23	48	45	85	2.39	−4.1	10	3,369	n.	35	n.	23	6	11	11	6.1	0.0	0.0
Red Bluff	330	5	58	29.66	30.02	−.09	52.7	+3.3	75	28	62	37	25	43	32	47	40	68	1.61	−2.3	7	3,277	nw.	24	n.	23	9	3	16	6.2	0.0	0.0
Sacramento	69	106	117	29.93	30.00	−.09	53.4	+3.3	68	24	61	39	21	45	24	50	47	80	1.35	−1.7	7	3,765	nw.	24	nw.	19	11	7	10	4.8	0.0	0.0
San Francisco	155	208	243	29.84	30.01	−.09	56.7	+4.5	69	28	62	48	23	51	20	51	46	72	1.10	−2.8	12	3,369	w.	26	w.	25	8	10	10	5.8	0.0	0.0
San Jose	141	12	110	29.87	30.02		54.6	+4.0	71	28	63	37	21	46	32				1.20	−1.2	9	2,740	nw.	22	nw.	19	7	9	12	6.3	0.0	0.0
South Pacific Coast Region							**58.0**	**+4.1**										**69**	**2.68**	**+0.5**									5.2			
Fresno	327	89	98	29.65	30.01	−.07	54.2	+3.1	69	18	64	35	20	45	27	49	44	73	0.67	−0.8	7	2,988	nw.	33	nw.	19	9	7	12	5.5	0.0	0.0
Los Angeles	338	159	191	29.60	29.96	−.10	60.7	+5.2	75	18	68	49	21	53	24	51	44	60	3.25	+0.2	7	3,722	ne.	24	n.	19	12	8	8	4.7	0.0	0.0
San Diego	87	62	70	29.87	29.96	−.10	59.2	+4.1	77	2	66	44	22	52	24	54	50	75	4.11	+2.1	9	3,557	e.	27	s.	3	8	10	10	5.4	0.0	0.0
West Indies																																
San Juan, P. R.	82	9	54	29.86	29.95		75.4	+0.5	87	5	80	66	18	70	18				5.84	+3.1	13	7,113	e.	42	n.	6	8	10	10	5.9	0.0	0.0
Panama Canal																																
Balboa Heights	118	6	97		[1]29.83	−.02	81.2	+0.9	93	28	90	70	7	72	21			[1]74	T.	−0.8	0	6,510	n.	25	nw.	7	1	24	3	5.5	0.0	0.0
Cristobal	36	6	97	[2]29.83	[2]29.86	−.03	81.8	+1.0	87	3	86	73	17	78	14	74	72	[1]75	0.97	−0.6	12	9,080	n.	29	n.	5	6	17	5	5.5	0.0	0.0
Alaska																																
Fairbanks	455	11	44	[2]29.03	[2]29.58		5.2		40	2	16	−28	28	−6	40	6	1	71	0.42		6	1,199	n.	19	sw.	2	7	4	17	7.1	6.2	12.5
Juneau	80	11	50	[2]29.60	[2]29.69		36.2		45	12	40	28	14	33	11	35	32	85	8.26		25	4,984	se.	31	se.	21	0	2	26	9.2	12.1	1.1
Hawaiian Islands																																
Honolulu	38	86	100	[2]30.09	[2]30.13		72.2	+1.4	78	17	76	65	4	68	11	65	62	72	0.50	−3.2	13	7,366	e.	29	e.	24	10	16	2	4.3	0.	0.0

[1] Observations taken bi-hourly.

[2] Pressure not reduced to mean of 24 hours.

TABLE 2.—*Data furnished by the Canadian Meteorological Service, February, 1931*

Stations	Altitude above mean sea level, Jan. 1, 1919	Pressure: Station reduced to mean of 24 hours	Pressure: Sea level reduced to mean of 24 hours	Pressure: Departure from normal	Temperature of the air: Mean max.+ mean min.÷ 2	Temperature of the air: Departure from normal	Temperature of the air: Mean maximum	Temperature of the air: Mean minimum	Temperature of the air: Highest	Temperature of the air: Lowest	Precipitation: Total	Precipitation: Departure from normal	Precipitation: Total snowfall
	Feet	*Inches*	*Inches*	*Inches*	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*	*Inches*	*Inches*	*Inches*
Cape Race, N. F.	99				30.2		36.2	24.3	44	0	8.09		17.0
Sydney, C. B. I.	48	29.80	29.85	−0.07	25.7	+6.4	32.4	19.0	42	−11	8.70	+4.61	35.0
Halifax, N. S.	88	29.76	29.87	−.08	26.7	+4.3	33.1	20.4	44	−3	4.07	−1.09	8.8
Yarmouth, N. S.	65	29.78	29.85	−.14	28.3	+2.5	34.2	22.4	45	5	5.62	+1.45	23.3
Charlottetown, P. E. I.	38	29.77	29.81	−.14	21.9	+4.3	28.1	15.6	45	−6	5.22	+2.16	48.8
Chatham, N. B.	28	29.81	29.85	−.11	17.7	+5.2	26.7	8.8	44	−25	2.77	−0.39	14.2
Father Point, Que.	20	29.95	29.98	.00	14.7	+3.2	22.3	7.1	38	−13	1.94	−0.27	19.4
Quebec, Que.	296	29.69	30.03	+.04	15.0	+3.2	21.7	8.2	37	−16	2.54	−0.73	25.4
Doucet, Que.	1,236				3.9		20.2	−12.4	45	−48	1.34		13.4
Montreal, Que.	187	29.80	30.02	.00	18.5	+4.0	25.9	11.1	36	−4	3.12	+0.05	23.7
Ottawa, Ont.	236	29.76	30.05	+.03	17.6	+5.9	28.0	7.3	44	−16	1.49	−1.20	14.2
Kingston, Ont.	285	29.72	30.06	+.02	21.9	+4.1	30.4	13.4	40	−8	1.17	−1.37	5.6
Toronto, Ont.	379	29.64	30.07	+.03	26.6	+5.1	33.2	20.0	43	0	1.13	−1.48	9.5
Cochrane, Ont.	930				10.0		19.5	0.6	38	−27	0.30		3.0
White River, Ont.	1,244	29.68	30.06	+.04	10.4	+10.2	26.0	−5.1	42	−41	0.67	−0.85	6.7
London, Ont.	808				26.8		33.9	19.8	44	2	1.99		13.8
Southampton, Ont.	656	29.32	30.06	+.04	23.6	+3.7	31.1	16.2	42	−5	0.96	−1.94	8.7
Parry Sound, Ont.	688	29.34	30.07	+.06	19.0	+4.7	27.3	10.7	37	−22	1.47	−1.45	14.6
Port Arthur, Ont.	644	29.36	30.10	+.05	21.5	+15.1	29.8	13.3	40	−11	0.24	−0.66	2.4
Winnipeg, Man.	760	29.24	30.11	+.01	17.9	+19.5	26.3	9.5	40	−21	0.18	−0.80	1.8
Minnedosa, Man.	1,690	28.20	30.10	+.01	19.2	+21.9	29.3	9.2	41	−28	0.06	−0.55	0.6
Le Pas, Man.	860				15.6		26.5	4.8	44	−23	0.11		1.1
Qu'Appelle, Sask.	2,115	27.70	30.01	−.07	25.9	+26.5	35.2	16.6	45	−16	0.22	−0.51	2.2
Moose Jaw, Sask.	1,759				31.2		43.0	19.4	58	−1	0.07		0.7
Swift Current, Sask.	2,392	27.36	29.94	−.13	31.6	+23.6	43.9	19.4	60	5	0.07	−0.67	0.7
Medicine Hat, Alb.	2,144												
Calgary, Alb.	3,428												
Banff, Alb.	4,521												
Prince Albert, Sask.	1,450	28.40	30.03	−.06	22.2	+25.2	33.8	10.7	45	−12	0.16	−0.53	1.6
Battleford, Sask.	1,592	28.20	29.99	−.10	26.6	+26.5	37.5	15.6	53	−2	0.03	−0.34	0.3
Edmonton, Alb.	2,150												
Kamloops, B. C.	1,262												
Victoria, B. C.	230	29.77	30.03	+.03	43.1	+3.6	47.4	38.9	51	32	3.22	−0.88	0.0
Barkerville, B. C.	4,180												
Estevan Point, B. C.	20												
Prince Rupert, B. C.	170												
Hamilton, Ber.	151												

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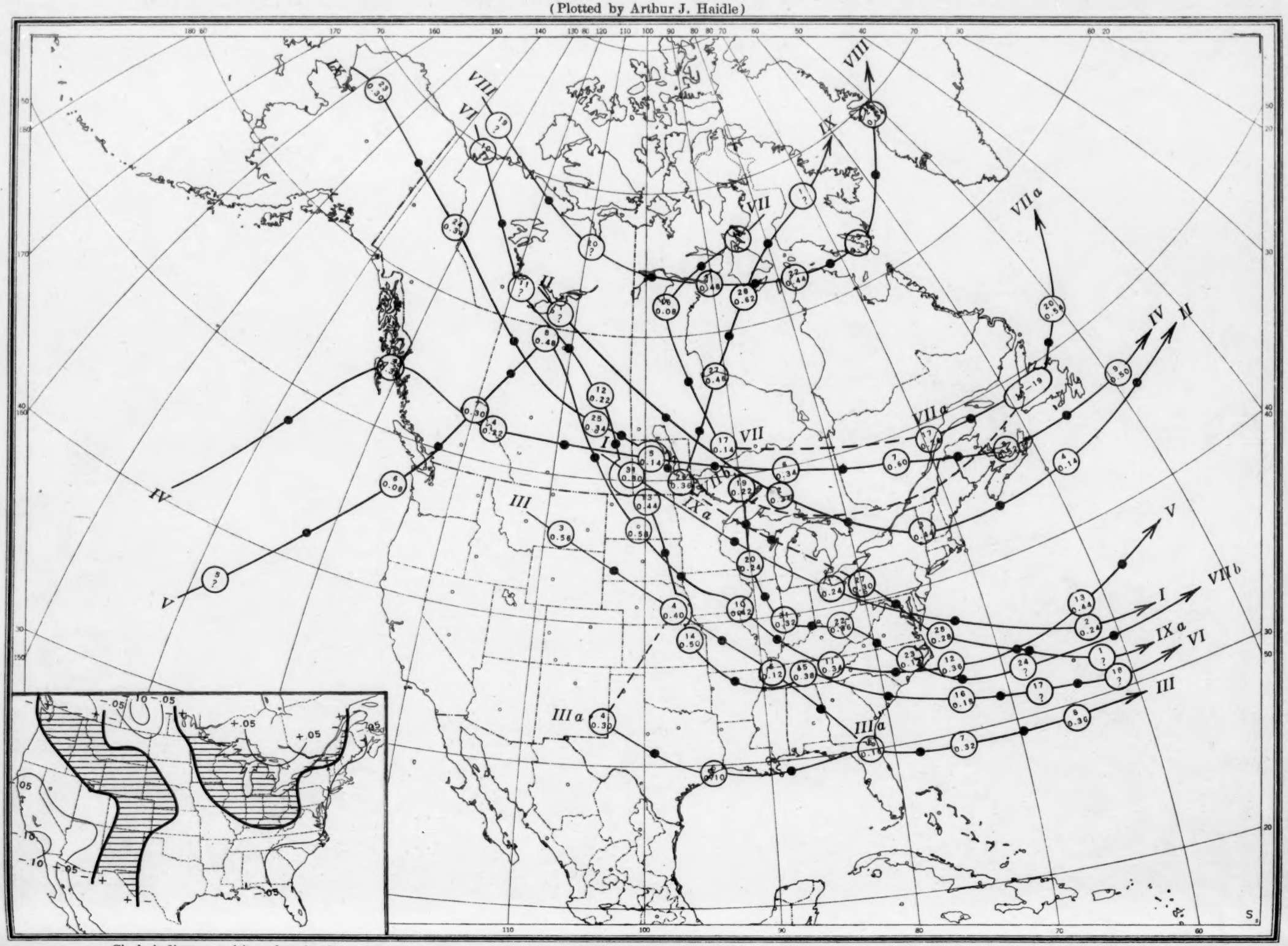
Toronto, Ont.	379	29.58	30.01	−.04	24.9	+3.5	31.6	18.2	45	0	2.62	−0.30	22.5
Estevan Point, B. C.	20				44.3		49.9	38.7	57	30	18.63		0.0
Prince Rupert, B. C.	170				42.6		46.6	38.6	57	30	14.08		0.0

Chart I. Departure (°F.) of the Mean Temperature from the Normal, February, 1931

Chart I. Departure (°F.) of the Mean Temperature from the Normal, February, 1931

Chart II. Tracks of Centers of Anticyclones, February, 1931. (Inset) **Departure of Monthly Mean Pressure from Normal**

(Plotted by Arthur J. Haidle)



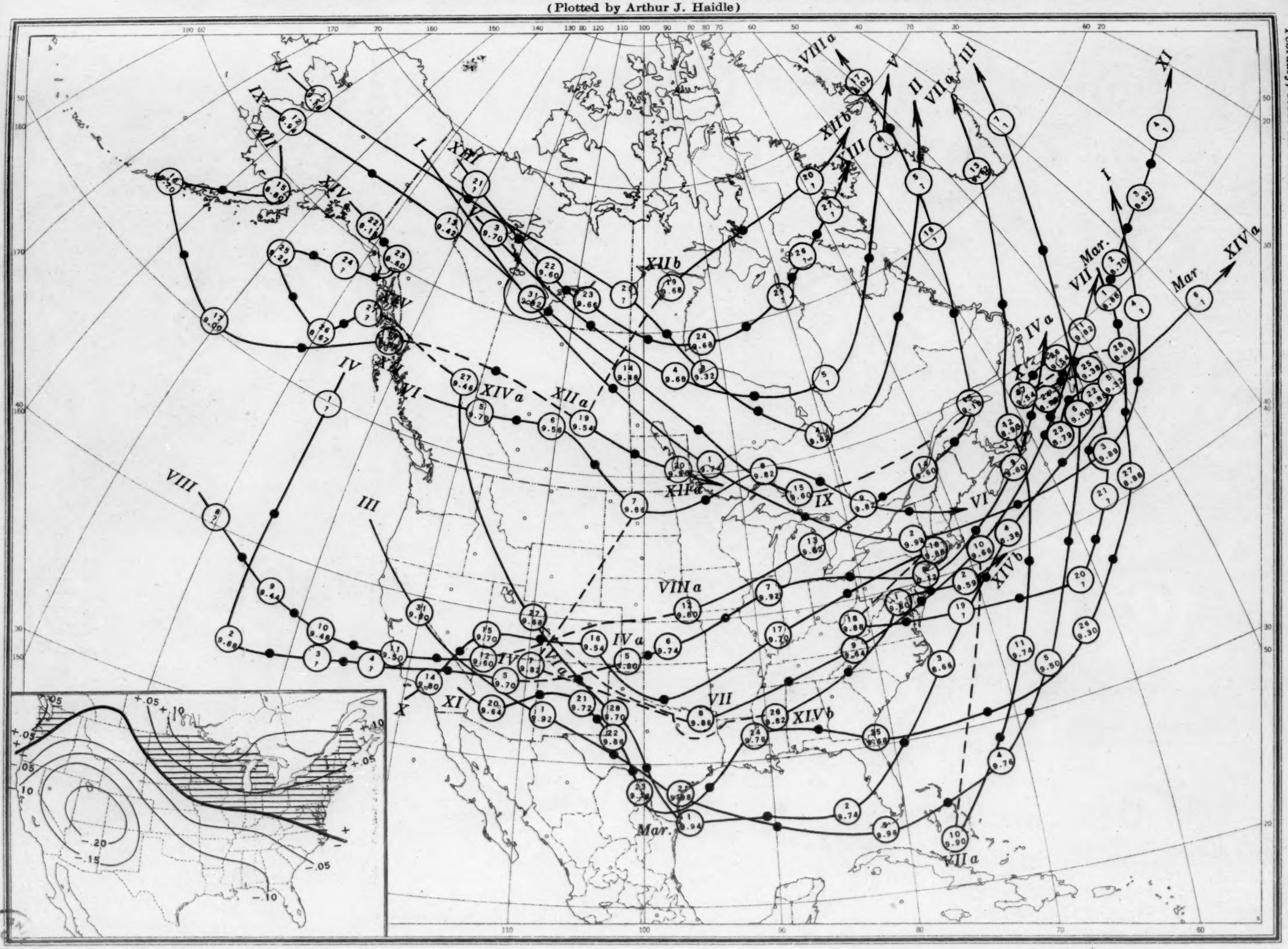
Circle indicates position of anticyclone at 8 a. m. (75th meridian time), with barometric reading. Dot indicates position of anticyclone at 8 p. m. (75th meridian time).

Chart III. Tracks of Centers of Cyclones, February, 1931. (Inset) **Change in Mean Pressure from Preceding Month**

Circle indicates position of anticyclone at 8 a. m. (75th meridian time), with barometric reading. Dot indicates position of anticyclone at 8 p. m. (75th meridian time).

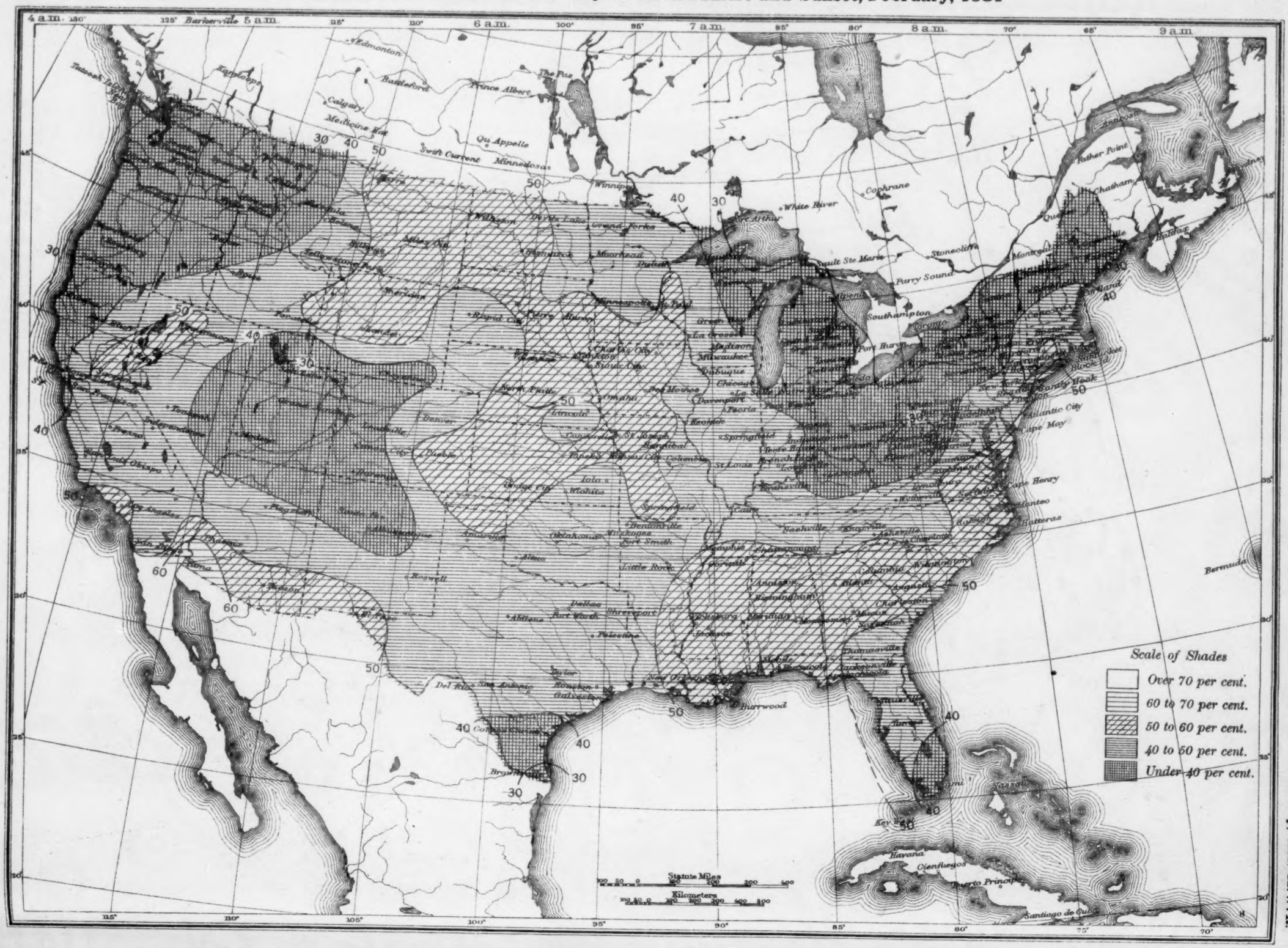
Chart III. Tracks of Centers of Cyclones, February, 1931. (Inset) Change in Mean Pressure from Preceding Month

(Plotted by Arthur J. Haidle)



Circle indicates position of cyclone at 8 a. m. (75th meridian time), with barometric reading. Dot indicates position of cyclone at 8 p. m. (75th meridian time).

Chart IV. Percentage of Clear Sky between Sunrise and Sunset, February, 1931



February, 1931. M. W. R.

Chart V. Total Precipitation, Inches, February, 1931 (Inset) Departure of Precipitation from Normal

Chart V. Total Precipitation, Inches, February, 1931. (Inset) Departure of Precipitation from Normal

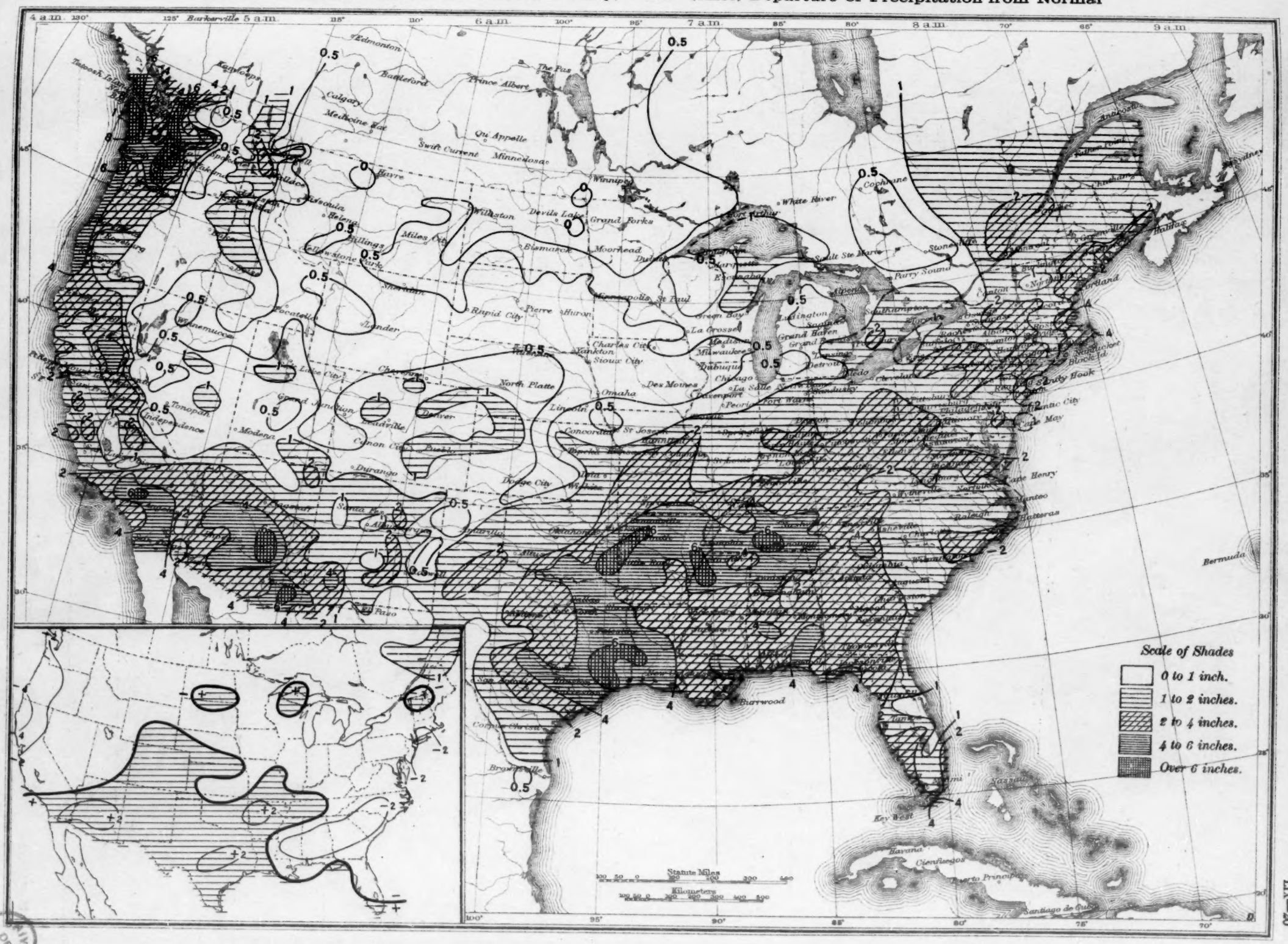


Chart VI. Isobars at Sea level and Isotherms at Surface; Prevailing Winds, February, 1931

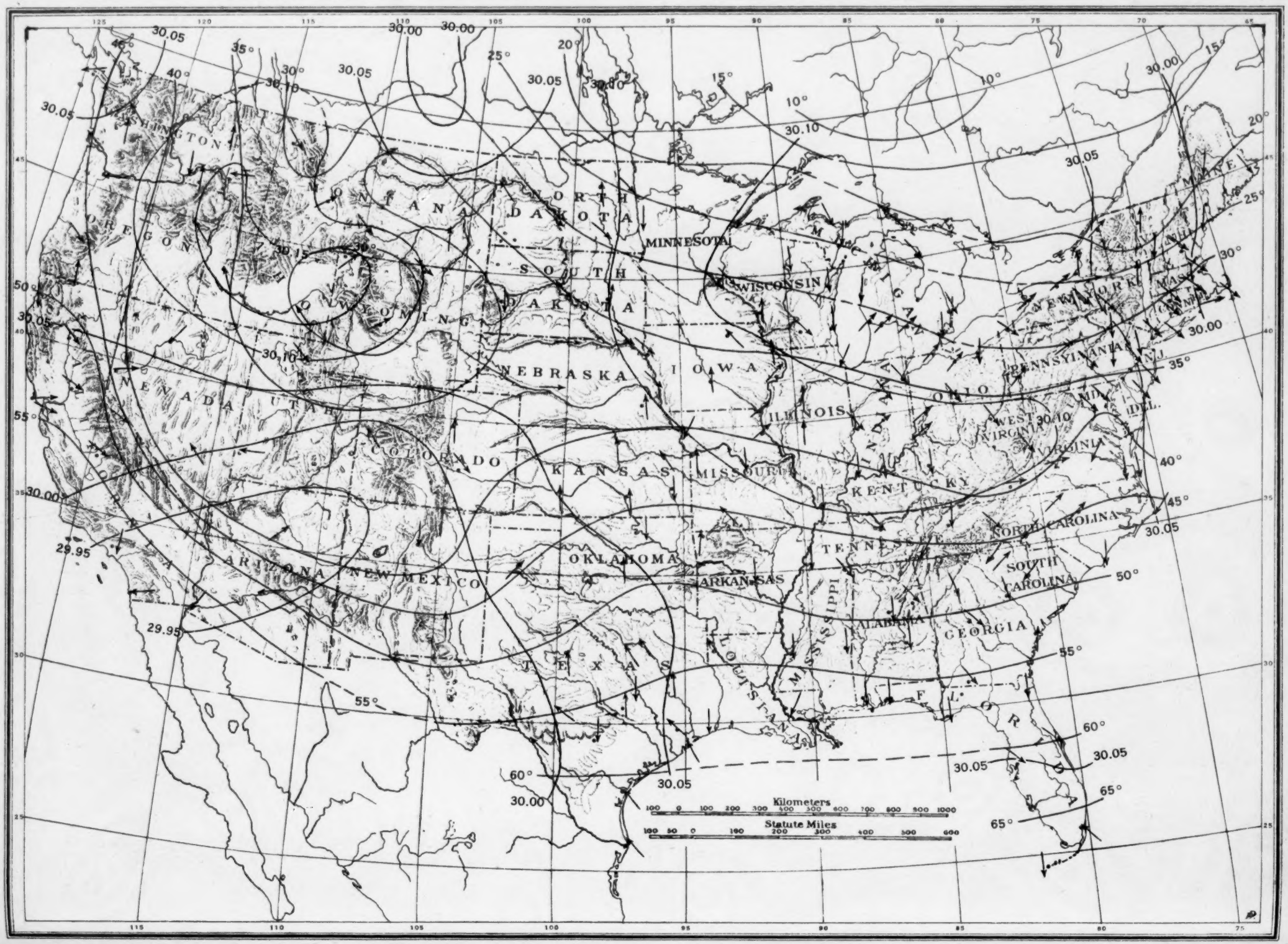


Chart VII. Total Snowfall, Inches, February, 1931. (Inset) Depth of Snow on Ground at end of Month

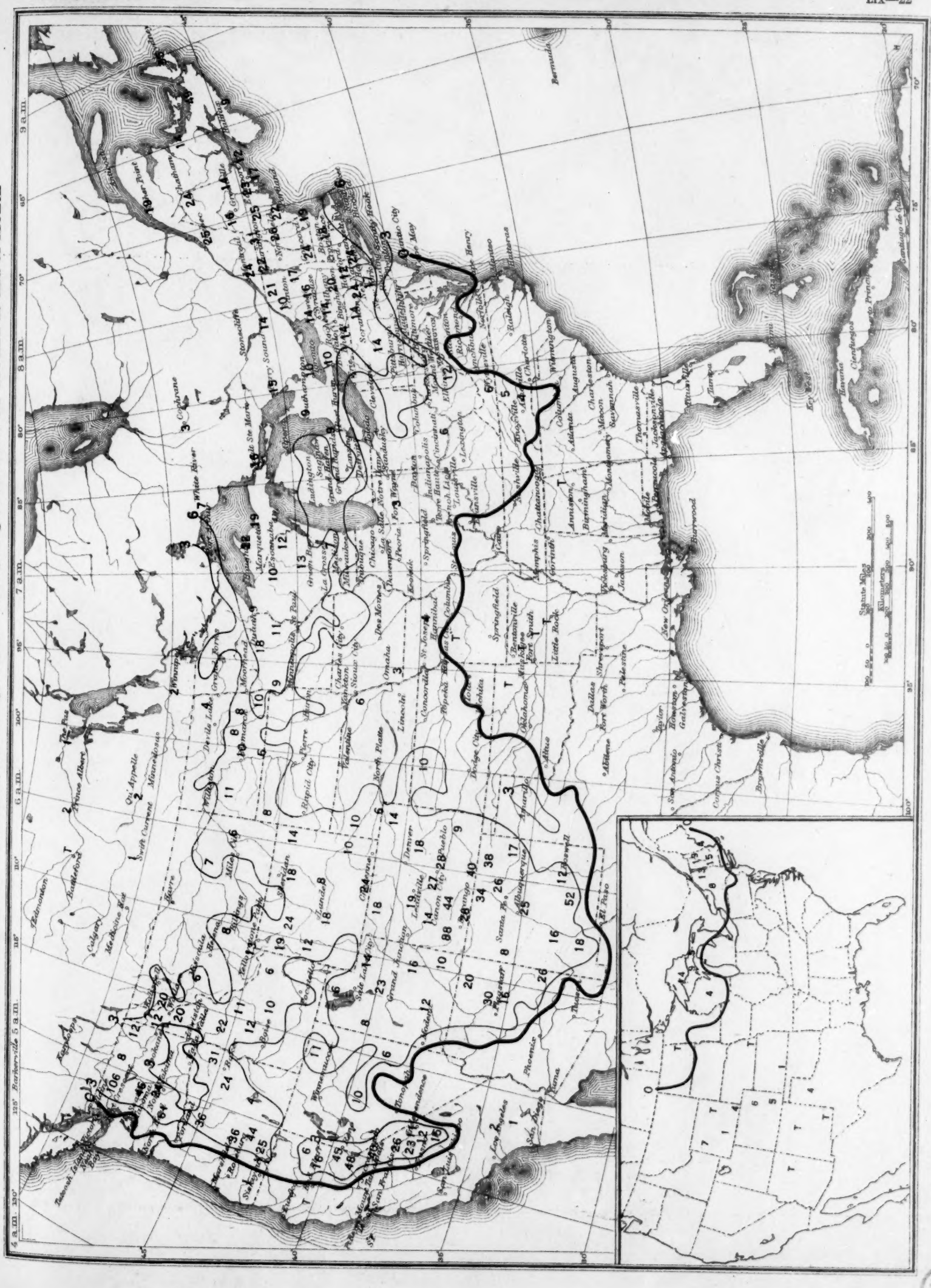

Bermuda
Havana
Key West
Nassau
Santiago de Cuba
Kingston
Port au Prince
Caracas
Cienfuegos
Barbados
Trinidad
Tampico
Vera Cruz
Mexico City
Monterrey
Chihuahua
Durango
Mazatlan
Guaymas
Hermosillo
Nogales
Tucson
Phoenix
Yuma
Los Angeles
San Diego
San Francisco
Sacramento
Portland
Seattle
Tatoosh Island
Victoria
Vancouver
Prince Rupert
Dawson
Whitehorse
Atlin
Prince Albert
Edmonton
Battleford
Calgary
Medicine Hat
Qu'Appelle
Swift Current
Moosejaw
Regina
Winnipeg
Pierre
Rapid City
Valentine
North Platte
Omaha
Lincoln
Concordia
Topeka
Kansas City
St. Joseph
Hannibal
Columbia
Springfield
Bentonville
Fort Smith
Little Rock
Oklahoma
Altus
Amarillo
Dodge City
Denver
Pueblo
Grand Junction
Salt Lake City
Modena
Winnemucca
Roseburg
Eugene
Astoria
Spokane
Kalispell
Havre
Miles City
Billings
Bismarck
Devils Lake
Grand Forks
Minneapolis
St. Paul
Duluth
Marquette
Escanaba
Sault Ste Marie
White River
Cochrane
Stonecliffe
Toronto
Port Arthur
Parry Sound
Sudbury
Owen Sound
Port Stanley
Windsor
Detroit
Toledo
Cleveland
Buffalo
Rochester
Oswego
Scranton
Binghamton
Albany
Boston
Portland
Eastport
Yarmouth
Halifax
Sydney
Grand Manan
Father Point
Quebec
Three Rivers
Montreal
Ottawa
Kingston
Belleville
Peterborough
Barrie
Parry Sound
Sudbury
Port Arthur
Fort William
Winnipeg
Brandon
Moosejaw
Swift Current
Medicine Hat
Calgary
Edmonton
Prince Albert
Battleford
Qu'Appelle
Regina

Chart VIII. Weather Map of North Atlantic Ocean. February 22, 1921

Chart VIII. Weather Map of North Atlantic Ocean, February 22, 1931

(Plotted by F. A. Young)

Greenwich Mean Noon.

Isobars show corrected barometric readings in inches of mercury.

Arrows fly with the wind.

Number of feathers indicate force, Beaufort scale.

Weather symbols are as follows:

○ clear, ◑ partly cloudy, ● cloudy, • rain, ▲ hail or sleet, ✳ snow, ═ fog.

Pointed arrows indicate land stations.

Pairs of numbers indicate temperatures of air and surface of water in Fahrenheit degrees. Upper number, air; lower, water.

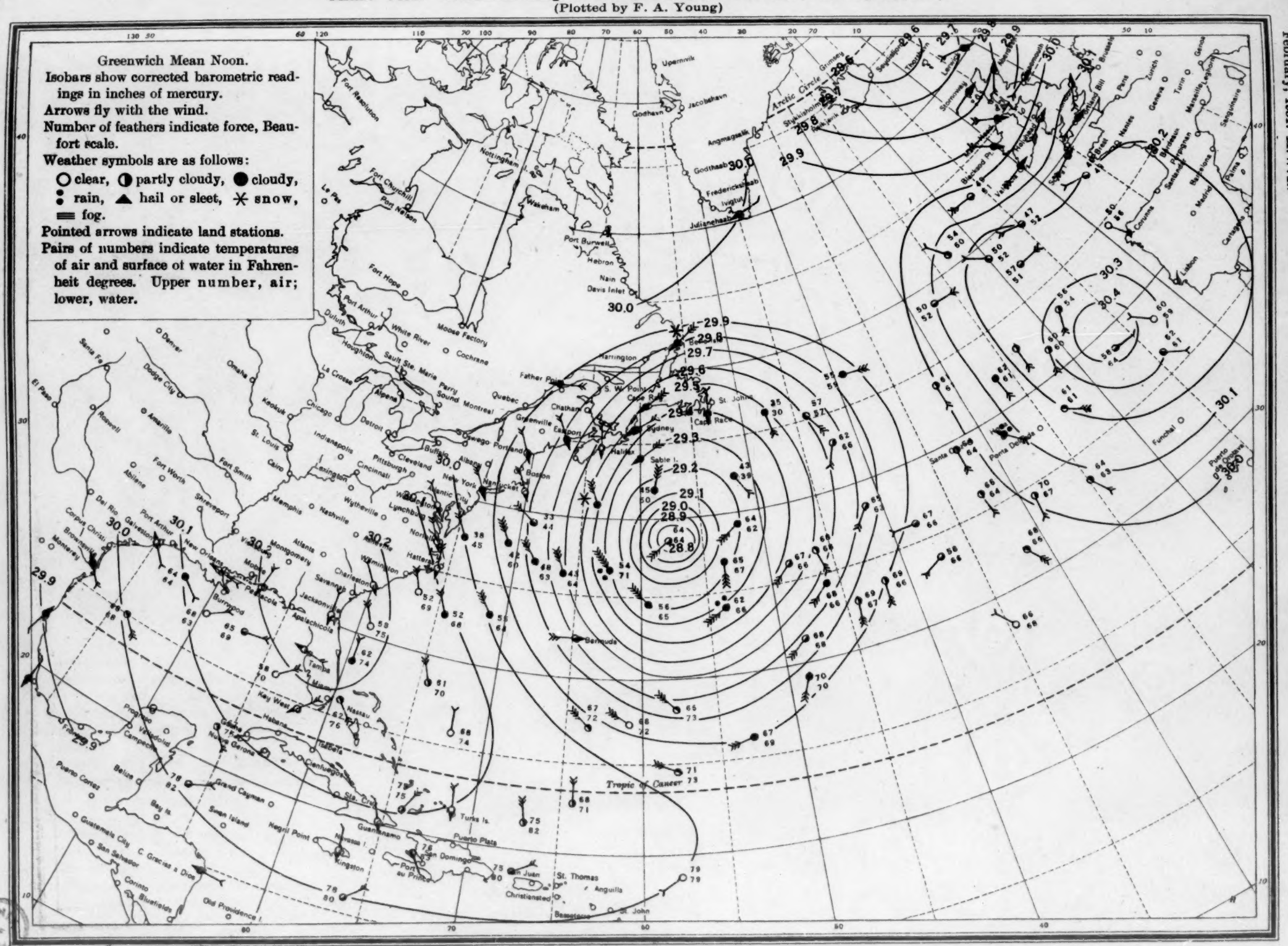


Chart IX. Weather Map of North Atlantic Ocean, February 23, 1931

(Plotted by F. A. Young)

Greenwich Mean Noon.

Isobars show corrected barometric readings in inches of mercury.

Arrows fly with the wind.

Number of feathers indicate force, Beaufort scale.

Weather symbols are as follows:

○ clear, ◑ partly cloudy, ● cloudy, • rain, ▲ hail or sleet, ✳ snow, ═ fog.

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Chart X. Weather Map of North Atlantic Ocean, February 27, 1931

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(Plotted by F. A. Young)

Greenwich Mean Noon.

Isobars show corrected barometric readings in inches of mercury.

Arrows fly with the wind.

Number of feathers indicate force, Beaufort scale.

Weather symbols are as follows:

○ clear, ◑ partly cloudy, ● cloudy, ⁝ rain, ▲ hail or sleet, ✳ snow, ≡ fog.

Pointed arrows indicate land stations.

Pairs of numbers indicate temperatures of air and surface of water in Fahrenheit degrees. Upper number, air; lower, water.

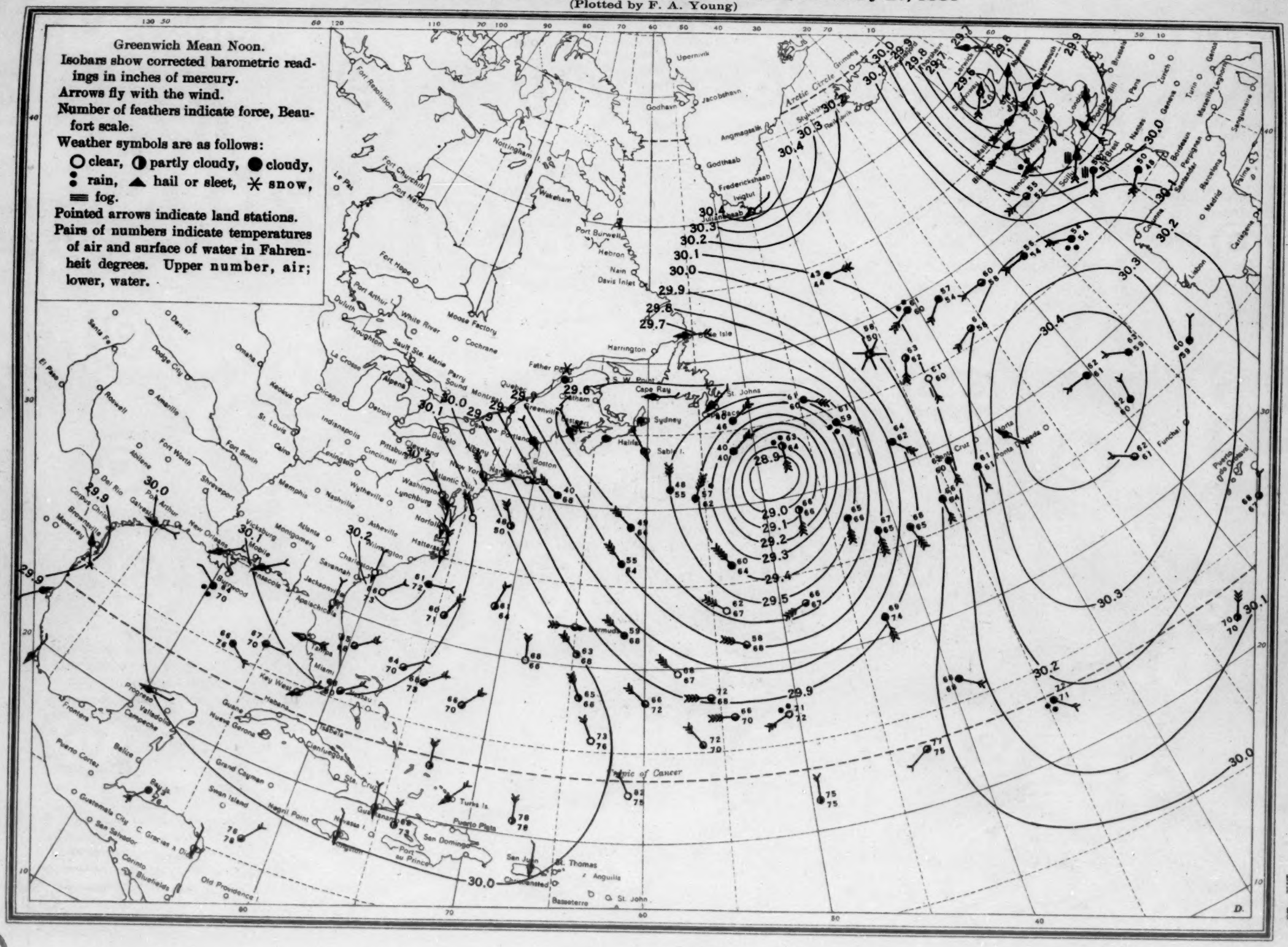

Chart XI. Weather Map of North Atlantic Ocean, February 28, 1931

(Plotted by F. A. Young)

Greenwich Mean Noon.

Isobars show corrected barometric readings in inches of mercury.

Arrows fly with the wind.

Number of feathers indicate force, Beaufort scale.

Weather symbols are as follows:

○ clear, ◑ partly cloudy, ● cloudy, ⁝ rain, ▲ hail or sleet, ✳ snow, ═ fog.

Pointed arrows indicate land stations.

Pairs of numbers indicate temperatures of air and surface of water in Fahrenheit degrees. Upper number, air; lower, water.